BRITISH MANUFACTURES.

CHEMICAL.

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BRITISH MANUFACTURES.

CHEMICAL.

INTRODUCTION.

The words *Chemist*, *Chemistry*, *Chemical*, &c., are associated with widely different meanings, in the minds of different persons. Some think that the only real chemist is one who keeps a "doctor's shop," wears a clean white apron, stands behind a nice mahogany counter, and dispenses his pennyworths of salts, pills, and magnesia. Others, knowing or hearing that crucibles, retorts, alembics, and other working apparatus, are used by the practical chemist of present days, and *were* used by the alchemist of earlier times, and learning also that there are in chemical operations certain curious transformations of liquids into opaque or transparent solids, metals into vapour, &c., entertain an idea that there must be something mysterious about chemistry, and that a chemist must be a sort of Dr. Faustus, a "cunning man" who sees farther than other people. A third class, better informed than the others, have an acquaintance, more or less general, with the great chemical truths developed by such men as Priestley, Lavoisier, Black, Dalton, Davy, Gay-Lussac, and Faraday; but, regarding chemistry in a purely scientific point of view, they are scarcely prepared to rank it as connected with one of our great branches of national manufacture.

When the matter is viewed, however, a little steadily, and is stripped of certain parts which do not properly belong to it, we can form a tolerably exact notion of the proper acceptation of the terms employed, and how it arises that reputed magic, mystery, science, manufacturing art, and shopkeeping, become mixed up in such an incongruous manner.

In the first place, it will be well to bear in mind that alchemy was the parent of modern chemistry, bearing some such relation to it as astrology bore to astronomy. The astrologer studied the movements of the planets and stars, under the idea that they had an influence over his destiny in this life, and that possibly he might obtain thereby a foreknowledge of what this destiny was to be: the search was a fruitless one, so far as regarded the immediate object in view; but he *did* observe the movements of the planets and stars, and thus accumulated a knowledge of a large number of facts which have been valuable working tools to astronomers of later times. In like manner the alchemist, entertaining a crude notion that coarse cheap metals might be transmuted into gold, set to work to discover the agency whereby this might be brought about; fortunes were wasted, families ruined, and heads made crazy, without attaining the object in view; but many curious facts were collected, in relation to the chemical action of different substances on each other, which have rendered great assistance to the more rational chemists of later ages.

We thus get rid of the confusion arising from associating chemistry with the dark and mystic proceedings of alchemy: we have only to consider that alchemy was an early and imperfect stage of chemistry; the mutual action of various substances on each other being studied—not, as in modern chemistry, for a practical and attainable object, but for an object which is now known to have been unattainable.

Next may be explained away the vagueness of association between chemistry and the retailing of medicines. Before the Reformation, there were no recognised professors of the healing art in this country; the monks and the alchemists being, in fact, almost the only doctors. The former laid claim to supernatural aid in the preparation of medicines; while the latter, not content with trying how to make gold, sought for an universal specific which should cure all ailments whatever. The grocers', or, as we should now call them, the chandlers' shops, were supplied with the few drugs then used as medicines, and the shopkeepers were wont themselves, occasionally, to act the part of doctors, and prescribe medicines for the ailments of their neighbours; while the barbers took to themselves the office of drawing teeth, letting blood, and performing the simpler kinds of surgical operations. But about three centuries ago the College of Physicians was established with a view of bringing the whole circle of medical operations under control; the selling of drugs, too, was afterwards separated from the selling of groceries. The *apothecaries*, to whom the drug department was intrusted, gradually assumed the privilege of attending patients, and also claimed the exclusive right to sell medicines; but they could not retain both privileges, and hence arose another class still, the *chemists and druggists*. These latter, considered simply as shopkeepers, are not necessarily supposed to know what medicines are suited to certain diseases; nor, on the other hand, are they simply retailers: as druggists, they sell in small quantities what they purchase in larger bulk; and as chemists or pharmaceutists, they study the means of preparing a mixed medicine from simpler chemical materials; requiring a certain knowledge of chemistry to effect this, but leaving to the physician or the apothecary the decision of the fitness of the medicine for the disease which it is intended to cure.

It will perhaps, therefore, clear up matters a little to say, that if the proprietor of one of these shops gives advice as to the treatment of any ailment, he does so as an *Apothecary;* if he sells a medicine, such as rhubarb, or salts, in the same state as that in which he bought it, but in smaller quantity, he does so as a *Druggist;* but if he prepares a pill, or mixture, or a compound medicine from different elements requiring different chemical modes of treatment, he does so as a *Chemist*, or a *Pharmaceutist*, or (to use the more convenient French term) a *Pharmacien.*

But the proper acceptation of the word chemist has yet to be considered. The pharmaceutist does not *discover* the chemical properties of bodies; he *applies* them, when discovered, to make numerous compounds. The real chemist, the man to whom the appellation in its highest sense is given, is he who discovers the great laws of chemical affinity, of definite proportions, of fusion, ebullition, vaporization, combustion, composition, decomposition, and all the many phenomena of a kindred nature. He does not, like the alchemist of old times, carry on his researches for a visionary and impracticable end; nor, like the physician, does he practically apply chemicals and drugs as healing remedies; nor, like the pharmaceutist and druggist, does he make medicines according to prescribed rules, or sell them by retail; but he seeks to establish those great truths with respect to the composition of bodies, which may be available to every one; and it is thus that men like Davy have attained the lofty position which their names occupy.

One other aspect under which chemistry is talked of and studied is still to be noticed; namely, its connexion with manufactures. What is a manufacturing chemist? What is the link which binds the science of chemistry with the industrial arts? These points are not difficult to answer. Many of the more important chemical compounds are so largely used in the arts, that nothing less than large manufacturing arrangements would be adequate to their production. Take, as an example, sulphuric acid (oil of vitriol): the scientific chemist studies the nature and composition of this acid, discovers that it is formed of two simple elements, detects the exact proportion in which these two elements exist in it, tries experiments as to its action on water and on various other bodies, and groups together distinct statements as to all the results which he is able to obtain; but he has not the facilities, nor is it a part of his object, to make this acid for sale. Again, the physician studies the effect of this acid, alone or in combination with other substances, on the human body; and the pharmaceutist studies the mode of bringing it practically into combination with other agents; but neither the one nor the other attend to the making of the acid itself. The manufacturing chemist takes this larger and more commercial part of the arrangement; and he therefore holds a middle place: being indebted to the scientific chemist for the discovery of the elements and properties of the substance to be made; and leaving to the physician, the pharmaceutist, the dyer, the calico-printer, and others, the study of the best modes of applying the substance, when made, to any practical purpose.

If these few explanations are borne in mind, they may perhaps help to remove some little ambiguity as to the meaning of words, by showing the different interpretations put upon the word "Chemist," and their relative bearings one on another.

This volume is intended to convey a general outline of the modes of manufacturing some of the chief chemical agents, as conducted in our own country in the present day. There are two reasons why the details will be limited to a few of the principal chemicals: 1st, because the space devoted to the subject is small; and 2ndly, because, on account of a general analogy observable in the manufacturing processes, one process becomes an index to many others. It will be useful, however, to preface the details by a notice of some of the chief chemical laws or principles which govern the processes of manufacture.

The most beautiful and valuable of these laws is perhaps that of *affinity*. By this is meant a tendency in two or more chemical bodies to unite and form one compound substance, the tendency being stronger in some instances than in others: what this affinity really is cannot be told; we know nothing more about its intimate nature than we do of gravitation: in both cases it is the *effect* which observers and experimenters regard, the agent itself being known only by the effects which it produces. If all bodies tended to unite with equal readiness, there would be no definitely compounded substance whatever, for every element would be strong enough to disturb every other, and all would be in confusion; but there is a kind of elective or preferential affinity, which prompts two bodies to combine together rather than either of them with a third, and this gives rise to some degree of stability in the compound substances with which we are familiar; because two bodies, when compounded together by the affinity existing between them, cannot be decomposed except by some agent having a stronger affinity for one or other of them. Hence it is one of the important objects of a scientific chemist to discover the relative strength of this affinity among a great many substances. It has been found, for example, that sulphuric acid unites more powerfully with lime than with magnesia; still more so with soda, and most powerfully of all with potash.

An immediate power of great value results from this elective affinity; for a manufacturing chemist, observing and acting upon these various degrees of strength, can produce one compound by decomposing another. A beautiful example of this will be explained in the body of the volume in reference to common salt: this consists of chlorine and sodium, but the two elements are not very strongly united, inasmuch as they can be separated by many different agents, and, by taking advantage of the different degrees of elective affinity, chloride of lime or 'bleaching-powder,' muriatic acid, carbonate of soda, and many other valuable bodies, may be produced mainly by the agency of common salt.

Another important principle is the difference of form which different bodies put on at the same temperature: some assume a hard earthy state, some a crystalline state, some a liquid, some a gaseous; and this is often made a means of separating the elements of a compound body. Water, for example, boils and passes off in vapour at a temperature of 212°, while spirit boils at a much lower temperature; and therefore by keeping a mixture of the two at a lower temperature than 212°, the spirit may be in part separated from the water: this is, indeed, the principle of distillation, however conducted.

The crystalline arrangement, too, is a valuable one to the manufacturer. It often happens that when several elements are compounded together in a liquid, one or two of them may be separated from the rest by allowing them to crystallize; this may be effected when one part of the compound has a tendency to crystallize sooner than the others. There is a very pretty exemplification of this in the making of alum, which we shall describe in a future page.

This principle (the difference in the form of different bodies at the same temperature) exhibits itself in so many ways, that the chemical manufacturer avails himself of it in almost every step of his progress. Two vessels, for instance, may contain two liquids, each composed of two different elements, and both liquids may be clear and transparent; but in adding these two liquids together, three out of the four elements may combine and form a ternary or three-fold compound, leaving the fourth to fall to the bottom of the vessel in a fine earthy state, so as to be easily separable from the liquid. In such case the fourth, or isolated element, has a less intense affinity or attraction for each and all of the other three, than they have for each other, and is besides of such a nature as to present a fine earthy or sedimentary texture at that temperature.

The relation which exists between heat and chemical elements is another great department of chemical science, which must be extensively known to the manufacturer before he can make his acids and alkalis, his salts and solutions. We are accustomed, in common life, to speak of all substances as being solid, liquid, and gaseous, each substance having some one of these forms definitely. So indeed they have, in reference to any one prescribed temperature: for instance, at a temperature of 130° tallow is a liquid, but wax is a solid; at 450° tin is a liquid, lead is a solid. But in taking a comprehensive and general view of the whole range of substances, there is reason to believe that the great bulk of them are susceptible of all the three forms, according to the heat which they contain. It is true that in some cases the attainable heat is never high enough, or the cold intense enough, to obtain these results; but *ice*, *water*, and *steam* will indicate our meaning as to the broad facts.

A manufacturing chemist has to make himself practically acquainted with the fusing-point (which separates solid from liquid) and the boiling-point (separating liquid from vapour) of a large number of substances; since it often happens that his only means of manufacturing one substance from another, consists in separating them at a particular fusing and boiling point.

Some very important points are involved in the grouping of chemical compounds into *acids*, *alkalis*, *oxides*, *salts*, &c.; forming, in fact, the very alphabet of many manufacturing processes. In the earlier times of chemistry, acid was the name applied to anything which was *sour* to the taste; but modern chemistry has greatly extended the application. They are, as now enumerated, generally but not always sour, having generally a great affinity for water, redden most vegetable blue colours, and combine readily with most alkalis, earths, and oxides of metal; some are solid, some liquid, and some gaseous; and nearly all of them contain either oxygen or hydrogen as one of the ingredients, every acid being a compound. Alkalis are also compound bodies, having several valuable properties, among which one is a strong tendency to combine with acids. Salts are the combinations of acids with earths, or alkalis, or metallic oxides, possessing properties often wholly different from those of the component ingredients; thus, sulphuric acid, a burning and powerful liquid, when combined chemically with the mild and inodorous substance magnesia, constitutes the peculiar crystalline 'Epsom salts,' a body essentially different in its properties from the substances of which it was made.

All these are points with which a manufacturing chemist must be well acquainted, since he has to avail himself of them in the process of manufacturing one substance from another. The complexity in the relations existing between different substances is greater than can possibly be conceived by those who merely view matters in their every-day phase; and yet this complexity must be reduced to something like order and regularity before practical rules can be deduced and laid down. It is indeed a startling fact, that all the objects which surround us on this earth; all that is within and upon the earth; the air which we breathe, and the birds which inhabit it; the waters, the rocks; the trees, plants, animals—all that can meet the eye and the ear on earth, whether living or lifeless, are made out of so few as fifty-four different substances! Though there are millions of distinct objects, yet (so far as the present state of science has revealed) it does not appear that there are more than this number of different elementary substances from which they are formed; most of the bodies with which we are cognizant being compounded of some two or more of these elements.

To any one who has paid a little attention to chemistry, these broad facts are well known; but a little elucidation may be desirable for some readers. The greater part of these elements are metals; but of those which are not metals, four of the most important are oxygen, hydrogen, nitrogen, and carbon. Now these four, in their simple and uncompounded state, are very little known to us in every-day life; but when combined two or more together, they form a surprising number of well-known substances. Of these a few may be here enumerated:—

Oxygen and hydrogen	form	Water.
Oxygen and nitrogen	in various proportions	Atmospheric air.
" "		Laughing-gas.
" "		Aquafortis.
Oxygen and carbon		Carbonic acid.
" "	in other proportions	Oxalic acid.
Hydrogen and nitrogen		Ammonia.
Hydrogen and carbon		Street-gas.
Nitrogen and carbon		Cyanogen (a gas).
Hydrogen, nitrogen, and carbon		Prussic acid.
Oxygen, hydrogen, and carbon (according to the proportions)		Sugar, starch, alcohol, acetic acid, and many other vegetable products.
Oxygen, hydrogen, nitrogen, and carbon (according to the proportions)		Albumen, fibrin, gelatine, gluten, and many other animal products.

The permutation of numbers, which form the arithmetical amusements of many a schoolboy, are not more surprising in their amount, while they are far less important in practice, than those among the fifty-four elementary substances; and when it is considered that the skill of a chemist—whether of a theoretical chemist who studies the laws of his subject, or of a manufacturing chemist who avails himself of those laws in practice—depends mainly on the extent to which he is acquainted with these permutations, it will not appear surprising that chemistry is deemed a progressive science, always advancing beyond the point from whence we started, and yet always showing that there is an indefinitely extended region yet to explore.

CHAPTER I.

CHEMICAL MANUFACTURES IN GENERAL.

Of the countless articles which every-day life presents to us, coming more or less under the general denomination of chemical substances, some are prepared quite in a domestic way, with very few appliances of skill or implements; some are brought to a saleable form by the shopkeepers who sell them; some are sold nearly in the state in which they are procured from mines or other natural sources; while others require the arrangements and extensive resources of large factories. There are some, too, such as soap, street-gas, porcelain, and baked earthenware, which, although not usually classed among chemical manufactures, yet involve so many of the peculiarities of chemical combinations as to be nearly allied to the others. For all these reasons a really strict selection of details for the present volume will be quite impracticable; and we shall have accomplished the object intended if we succeed in giving a slight outline of some of the broader features of the subject.

Generally speaking, the chemical works, strictly so called, are those in which the more important of the acids, alkalis, and salts are made; such as sulphuric, nitric, and muriatic acids; soda in various forms, chlorine, alum, metallic salts, &c.; while other factories are designated from the kind of substance made, such as white-lead works, colour works, &c. But all of them are influenced both by political and by scientific events in a remarkable degree.

That such establishments should be affected by the current of scientific discovery is what may reasonably be expected, since every advance in our knowledge of the constitution of bodies is likely to work changes in the modes of producing those substances. But in what way political matters are found to bear on the question may not be so obvious. A few considerations will, however, tend to show the kind of connection between these apparently disconnected agencies. If a manufacturer prepares certain chemical substances (say) from sulphur; and if political, or diplomatic, or fiscal disagreements should occur between England and the country whence this sulphur is produced, then the manufacturer might be constrained to procure his sulphur from some other source, perhaps by a complicated process on one of the English ores of sulphur. Again, suppose the English government removes the tax previously imposed at a heavy rate on some article of abundant supply, such as common salt, then the manufacturer may be induced to employ this material as a fund whence he may procure acids or alkalis previously procured from a more expensive source. Now these are not merely supposed cases; they have actually occurred within the last few years, as we shall show farther on; and they illustrate the kind of effect which legislative or political occurrences are calculated to produce on chemical manufactures. The imposition or the removal of an excise duty on a commodity of home production; the imposition or the removal of a customs' duty on an imported foreign product; the establishment or the cessation of commercial intercourse with a country richly provided with some commodity which we require in our manufactures; the concentration, in the hands of a few, of a commodity required by the many; the legislative enactments which occasionally give rise to a demand for a particular commodity at a particular time; – all or any of these may work great changes in the arrangements of an establishment where chemical manufactures are carried on, irrespective of the still greater changes which naturally result from scientific discoveries in chemistry.

Chemical manufactures, like most others on a large scale, are carried on chiefly in the midland and northern counties. In most instances the chemical works are situated somewhat beyond the precincts of a large manufacturing town, since they require more space than can conveniently be procured within a town, and are liable to give off vapours and gaseous products, which are better at a distance than in close proximity to dwelling-houses. They are also generally situated near seaports, for convenience of shipment. Glasgow, Newcastle-upon-Tyne, and Liverpool are perhaps the three principal centres for this class of manufactures. With respect to Glasgow, Dr. Thomson, at the meeting of the British Association in that city in 1840, gave some interesting details respecting the chemical manufactures of the district. He alluded especially to the vast works at St. Rollox, in the northern suburb of the city, where the furnaces and buildings extend over an area of ground unparalleled, we believe, by any similar works, and where a giant chimney rises to a height exceeding that of St. Paul's by a hundred feet. The factory was first established as sulphuric acid works in the latter part of the last century; they were at first small in size, and have risen to their present state by slow degrees. Besides this acid, bleaching-powder, or chloride of lime, is made at these works, a material of vast importance in reference to many branches of manufacture. Soap and other articles are also made at St. Rollox. Dr. Thomson also alluded to the alum manufacture, for which there are two establishments near Glasgow; one of these we shall notice further on; while at the other, besides alum, is made prussiate of potash and prussian blue. In another chemical factory near Glasgow is made, among other things, bi-chlorate of potash, highly useful to calico-printers; in another, acetic acid and pyroxalic spirit are distilled from wood; in others iodine; so that, taking the whole of these collectively, Glasgow may be deemed one of the chief centres of manufacturing chemistry.

The neighbourhood of Newcastle, too, is deserving of attention in this respect. The busy Tyne exhibits along both its banks, all the way from Newcastle to Shields (a distance of seven or eight miles), a continued succession of factories—here of glass, there of coarse pottery; at other spots, of chemicals, of lead, iron-works, oil-mills, engine-factories, and others which tend to swell the importance of this bustling and thriving neighbourhood. Of these seats of manufacture, the chemical works are the most conspicuous, from the enormous height of their chimneys. No other factories or works have such lofty chimneys as chemical works, because no others give forth so many gaseous products likely to be of a deleterious character. In some of these instances (as we have just intimated) the chimneys considerably exceed St. Paul's

Cathedral in height. In past times many of the chemical works were regarded (and correctly so) as pests and plague-spots, bringing desolation on all the vegetable products near them; blasting the trees, and stunting the growth of almost every kind of field and garden produce. Numerous were the disputes between the various parties on these points; and an avowed good was, in this respect, always accompanied by an equally avowed evil. But modern research has wrought surprising changes in this respect. Every year adds something to the list of processes whereby a deleterious gas, previously sent forth into the atmosphere, becomes a source from which other and valuable products are derived; and it is scarcely too much to expect that such improvements will gradually be made as to render the lofty chimneys less and less necessary—leaving them as memorials of a past and less skilful state of the manufacturing arts.

The Tyne separates Newcastle from Gateshead, the latter being to the former what Southwark is to London; and at a distance of a mile or two eastward from Gateshead is one such chemical work, which may be regarded as a type of the rest. The works occupy a position between the South Shields Railway and the river; and like most places in the neighbourhood, have abundant means of intercourse with the great central depôt, Newcastle, by cheap railways and still cheaper steam-boats. The Londoners have their fourpenny steamers, but the good folks of Newcastle can have a nine miles' trip for threepence; and this facility, together with railways running along both banks of the Tyne, gives rise to an incessant and extensive intercourse.

On approaching the works, it is soon evident that they are of the class where a large number of buildings are spread over a great area of ground, rather than exhibiting one huge building, such as is so often seen in the cotton districts. The buildings are of various sizes and shapes: some lofty, some shallow; some long and broad, others nearly square; some exhibiting within dry and dusty processes, others heat and vapour, others vessels and liquids; one with a lofty and well-proportioned chimney, others with chimneys of more humble dimensions. Narrow passages and square courts separate these buildings one from another; and while passing through these passages, and the buildings adjacent to them, every one must become sensibly alive to the odour of the acids and other chemicals under process of manufacture.

Common *sulphur* and common *salt* are now the two great agents in the production of the chemicals in most familiar use. Sulphuric acid, or 'oil of vitriol,' chloride of lime, or 'bleaching-powder,' muriatic acid, or 'spirit of salt,' the soda-ash employed by glass-makers and soap-makers, the common soda employed in washing—all result from certain modes of applying one or other of these cheap and abundant substances; and these are precisely the commodities most generally made at chemical works. Nothing can more beautifully illustrate the general character of chemical composition and decomposition than the steps by which one substance becomes transformed into another, as developed at a chemical work: the production of an acrid and poisonous body from harmless ingredients; the production of a liquid from two gases, or of a gas from two liquids; the generation of colour from the mixture of two colourless bodies; the transformation of an opaque earth into a colourless crystal;—these and analogous phenomena are constantly presented during the progress of chemical manufactures.

Sulphur and salt being thus two of the most valuable sources of chemical commodities, it may be well to devote a chapter to them in their individual form, before tracing their subsequent transformations.

CHAPTER II.

ON SULPHUR AND SALT, AS SOURCES WHENCE OTHER COMMODITIES ARE OBTAINED.

There is nothing so very especial in the nature of these two chemical substances as to lead to their being grouped together, and being placed distinct from others, were it not that they are so singularly valuable as sources whence other commodities may be obtained. As, however, there are some interesting chemical details connected with the original production and extraction of these valuable articles, we will collect from different sources a few facts on the matter, commencing with

Sulphur

There may perchance be those who would ask—" Of what use can sulphur be, except to make matches ? " That it has numerous other uses, however, will be readily conceded when we state, that although an enormous quantity of the article is produced in our mining districts for home consumption, yet so great is the demand for it, that forty or fifty thousand tons are annually imported from Sicily !

Sulphur is an abundant article in the neighbourhood of volcanoes. It is widely diffused throughout the mineral kingdom, but is more abundant in some places than in others. In Iceland it is found in combination with gypsum ; at Conil, near Cape Trafalgar, it occurs in a crystalline form; at Urbino in Italy, at Aragon in Spain, and at Lauenstein in Hanover, large quantities are found. Beds of sulphur are very numerous in the tertiary blue clay of Sicily, a country which has supplied the greater part of Europe with sulphur for centuries, without any sensible diminution of its own stock.

The principal scene of the mining operations in Sicily is near Catolica. The sulphur appears in veins of various colours, mixed with clay and gypsum. The general appearance is that of a shining grey colour, but large pieces are found which are red and transparent, and are called by the workmen *virgin sulphur*. Large black patches also appear, consisting of a chemical combination of clay and sulphur: these patches contain beautiful crystals of sulphate of lime of various colours—yellow, violet, grey, and black.

The preparation of sulphur in Sicily, for exportation, is a very simple affair. Large cauldrons are formed in an elevated mound of earth, each cauldron being about seven feet in diameter and five feet deep. Large masses of the sulphur-stone are piled up round the edge of each cauldron, and gradually inclined so as to meet in a point at the centre; thus forming a sort of conical mound or cover over each cauldron. The spaces between the large masses are filled up with smaller lumps, and these again with dust of the same material. A quantity of straw is then spread over the mound and ignited; the straw burns, and the fire soon extends to the interior; so that the sulphur, as it melts, flows down into the cauldron. After this process has continued for about eight hours, the melted sulphur is drawn out at an aperture in the lower part of the cauldron, and received into wooden moulds which have been previously wetted to prevent the sulphur from adhering to them. In about a quarter of an hour the sulphur becomes solid, and is then fit for exportation. In this state it is called *block sulphur*, and sometimes *massive* or *native sulphur*.

Vast quantities of sulphur are procured in our copper-smelting districts, under the name of *roll* sulphur, from the cylindrical shape in which it is cast. Most metallic ores, in the state in which they are dug from the earth, contain sulphur. The iron and copper pyrites, which so greatly enrich England, are compounds of those metals and sulphur. In the smelting of copper-ore, the sulphur is separated from the metal, melted in earthen pots, and cast into wooden cylindrical moulds which give it the form of rolls.

Another form in which sulphur is obtained is that of a powder, called *flowers of sulphur*. The sulphur is melted in a vessel called an alembic. At a temperature of about 600° the sulphur rises in the form of vapour, which being collected in the upper part of the alembic, cools down into the form of flowers of sulphur. This process is called *sublimation*. Products obtained in this way were supposed by the alchemists to resemble the flowers of plants; hence the name: but the peculiar resemblance which they saw, or fancied they saw, is not very clear.

Sulphur is an elementary body; that is, the chemist has never been able to resolve it into simpler parts. We need scarcely refer to its pale yellow colour, as it is so well known. Its weight is about twice that of an equal bulk of water. When rubbed with a piece of warm flannel, it becomes negatively electrified. One curious consequence of this property is frequently noticed by the druggist: in grinding a piece of roll sulphur in a dry

Wedgwood mortar, the resulting powder adheres with considerable force to the mortar, and will not fall out when the mortar is inverted: the reason is, the sulphur becomes negatively electrified by friction, and the mortar positively electrified; and according to a well-known law of electricity, two bodies in opposite electrical states attract each other. Hence the adhesion of the sulphur to the mortar.

Sulphur is insoluble in water and in alcohol; but hot oil and some of the alkalis will effect its solution. It is very brittle. If a roll of sulphur be grasped by a warm hand, it will often break to pieces in consequence of its unequal expansion by heat. When exposed to heat a little above that of boiling water, it melts; at 230° it is almost as liquid as water; by raising the temperature to 600°, its colour changes from a light to a deep yellow, then to orange yellow, then a shade of red comes over it, then brown, and at its boiling-point its colour is brownish red; but the most remarkable circumstance is, that increase of temperature, so far from rendering sulphur more fluid, as is the case with most other bodies, actually thickens it, and produces a thick viscid mass: thus at 230° sulphur is quite liquid, and can be poured out of the vessel containing it; at 338° it begins to be viscid; at 428° it becomes quite thick; and from 464° to 500° the vessel containing it may be turned upside down, and the sulphur will not flow out; as it approaches the boiling-point, it becomes less viscid. These remarkable facts have not been explained. When sulphur is pure, it boils away at about 600°, and leaves no residue.

If a quantity of sulphur be melted in a pipkin, and then set aside to cool, the surface will soon become solid.

If we make two holes in the crust, near the edge, but opposite to each other, and incline the vessel, the melted sulphur will flow out into any other vessel placed to receive it, and air will enter at the other hole. On allowing the pipkin to cool gradually for a few hours, we shall find, on breaking open the mass, that the interior crust is composed of an immense series of small and beautiful crystals.

The above are a few points relative to sulphur and its properties generally; but we will abstract from the 'Journal of the Statistical Society' a somewhat fuller notice of the mode of procuring it in Sicily:—

"The Sicilian sulphur is found within the limits of a geographical line which commences at the river Maccasoli in the valley of Girgenti, runs northward as far as Lercara in the valley of Palermo, tends eastward to Centorbi in the valley of Catania, and thence runs south-westerly to Terranova in the valley of Caltanizetta, where it terminates. The area of the sulphur district is about 2600 English square miles. Destitute of timber, and diversified only by fruit-trees scattered around the villages, it has few charms for the passing stranger beyond the fantastic shape of its cliffs and mountains. The man of science, however, who examines its soil, will find it replete throughout with objects of interest. The sulphur territory, the formation of which is tertiary, presents successive strata of shell, limestone, white and blue marl, intermixed with banks or beds of gypsum, and occasional patches of cretaceous matter. The sulphur is found imbedded in the lowest stratum of blue marl, which is distinguished from the upper one by the entire absence of shells. The district contains about 150 distinct mines, which are capable of yielding from 750,000 to 800,000 cantars (about 50,000 to 80,000 tons) annually. Of the richest mines, those of Gallizzi, Sommatino, and Favara, the yearly production has been 100,000, 80,000, and 60,000 cantars respectively.

"The visitor to a sulphur-mine usually descends by a plane or staircase of high inclination to the first level, where he finds the half-naked miner picking sulphur from the rock with a huge and heavy tool: boys gathering the lumps together, and carrying them up to the surface; and, if water be there, the pumpmen hard at work draining the mine. A similar scene meets his eye in the lower or second level. Above-ground the sulphur is heaped up in piles or fusing in kilns.

"Every stranger must be forcibly struck with the hardy and healthy look of the miners and burners, to which the lean and sickly aspect of the southern population forms a thorough contrast. The life of a pickman, which is sometimes said to be hard and wearisome compared with that of the peasant, is in reality easy, and suitable to Sicilian taste. His working days do not exceed 250 in the year, and his hours of labour are only six in the day. Left, therefore, with eighteen hours a day to himself, he passes three-fourths of his time in eating, drinking, sleeping, and lounging about his village. Satisfied with animal existence, the pickman seeks not intellectual pleasures at the cost of increased exertion. His wages rise and fall with the price of the mineral; from 16*d.* to 20*d.* a day for himself, and about half as much for each of his boys, are reckoned good earnings. The pumpmen are ill-paid labourers compared with the pickmen. Their daily toil, if lighter, is longer and less intermitted; and their occupation is productive of sickness rather than conducive to health. Constantly drawing in sulphuretted hydrogen gas, which escapes from the agitated water, they suffer so severely in their eyes as often to become blind for twenty-four hours. They work for eight hours a day, and earn from 1*s.* to 1*s.* 4*d.* each. The burners, who extract the sulphur, by fusing the ore in kilns made of gypsum and stone, or sometimes in close vessels or furnaces, usually earn about 1*s.* a day.

"The sulphur thus obtained by liquation, when hardened into cakes, is taken down to the coast by carriers and muleteers. These are mostly small farmers, who are paid by the load, according to the time of the year and the demand for their services. Being seldom trustworthy people, these carriers are engaged by a warranter, who, for less than 1*d.* a cantar, becomes answerable for the safe delivery of the sulphur at the shipping-place. To Palermo and Catania the sulphur is conveyed in carts; to the southern ports it is carried down on mules and asses.

"Such is the working part of a mining establishment. The overlookers are mining-captains, clerks, and a manager. The mining-captain, chosen from among the pickmen for his knowledge of the mine, examines the veins and directs the operation. As the right-hand man of the manager, he is looked upon by the pickmen and others as a person whose good opinion it is worth while to cultivate. Living in a substantial and commodious house, and dressing in a neat and becoming manner on Sundays and holidays, he holds a respectable place in village society. He usually resides a few miles from the works; but in some cases he dwells at the mine, where he is required to be in constant attendance from morning till night. His wages are from 2*s*. to 4*s*. a-day; but many unlawful perquisites raise his earnings to a higher amount. After a few years' constant employment in a rich and extensive mine, he is usually able to retire with a competence sufficient for his limited wants. The clerks and watchmen, who keep account of piece-work and labourers' time, who receive the fused sulphur and weigh it out to the carriers, and who reside at the mine to take care of the works, usually earn from 1*s*. 8*d*. to 2*s*. 8*d*. a-day. The manager or head-agent acts as treasurer and trustee for the owners or lessees of the mine. Aided by the mining-captain and the clerks, he engages and pays the workmen, and keeps the general accounts. His salary is from 4*s*. to 6*s*. 8*d*. a-day. His gains are perhaps double this amount; so that he often makes his fortune in the course of a few years.

" The number of persons regularly employed in the sulphur-mines has been estimated at 4400, viz.:—1300 pickmen, 2600 boys, 300 burners, and 200 clerks and others; to which if 3600 persons occasionally employed, viz., 2600 carriers, and 1000 wharfingers, be added, the total amount will be 8000 persons more or less engaged in the extraction of ore and the exportation of sulphur. A small portion of the sulphur carried down to Girgenti serves for the use of a royal refinery, whence it is exported to France and Austria in powder and in rolls. Previous to the sulphur contract the chief part was sent in cakes to England, France, Holland, Russia, and the United States, in the proportion of three-sixths to England, two-sixths to France, and the rest to other countries.

" In the Sicilian market sulphur is divided into first, second, and third qualities of Licata (each of which is subdivided into best, good, and current), and into first and second quality of Girgenti, with the like subdivisions. The first and second qualities of Girgenti correspond with the second and third of Licata."

Salt.

We now transfer our attention from sulphur to salt, and show the general nature of its origin by describing salt-work operations in two or three different countries.

Three French gentlemen many years ago published a description of the Salzburg Salt-Mines; and, as this is deemed to be very correct, we will here transcribe it:—

"The salt-mines are at a little distance from the small town of Hallein, and at the foot of the Durenberg mountain. We seated ourselves in sledges, and were conveyed to the opening which leads into the interior of the mine. Before descending into the mine we equipped ourselves in the costume of the miners, which consisted of flannel waistcoat and trowsers, and a large white cape for the shoulders. These preparations are rendered necessary by the extreme humidity of the mine, which would effectually have destroyed the common articles of clothing. We were also supplied with strong shoes, a leathern apron, and a hood. We then seated ourselves on a sort of wooden horse called a 'wurst,' which moved on four small wheels. Three of the miners attached the traces of this machine around their waists, and dragged us slowly through a long gallery, on each side of which was an aqueduct constructed of wood. One of these conveyed a supply of fresh water into the mine, and the other carried it off when it had become sufficiently impregnated with salt. In a quarter of an hour we reached the first shaft. It is not dug in a perpendicular direction, but inclines at an angle of about 45°. It was along one of these that we were to descend to a depth of about eighty yards.

"The descent is effected in the following manner:—Two round and smooth beams are placed side by side on the lower part of the shaft, about a foot asunder. They somewhat resemble the machine used by brewers for lowering beer into cellars. They are fixed, and extend from the entrance to the bottom of the shaft. Upon these beams the person descending seats himself, placing his legs over each side, and thus slides to the bottom. A great rope is stretched on the right, about the height of the arm, in order to enable those who are descending to regulate the rapidity of their descent. One of the miners preceded each of us in the descent. My attendant placed himself between my legs, at the same time cautioning me neither to move my arms nor feet. The men then asked us if we were alarmed? to which, of course, we courageously replied in the negative. Then, abandoning ourselves to the impulse of our own weight, and each of us holding in one hand a burning torch, we glided forward so rapidly, that we were at the bottom of the 'rolle,' or beam, in half a minute. We then proceeded along another gallery, similar to the one at the entrance of the mine; and descended still deeper into the mountain by two other rolles, on which, profiting by my previous experience, I kept my seat without assistance. This mode of descending was both easy and pleasant, and I even regretted that the fourth rolle was the last.

"The mountain within whose bosom we now were, is composed of a sort of rock-salt, which is in a constant course of growth or formation. The first excavations appear to have been made at a period so remote, that tradition has not even preserved any records of the date at which the working of it was first commenced. These excavations consist of chambers six or eight feet square, into which water is conveyed by means of the aqueducts before-mentioned. The water enlarges these chambers by dissolving gradually the walls and roof. They are generally about six feet in height, and are filled as nearly as possible with water. If the chamber were half filled with water, the sides only would be submitted to the process of solution, but, by being very nearly filled, the water attracts the saline matter contained in the roof, and the operation is carried on in the most rapid, and at the same time effective, manner. The miners term the roof of the chambers the 'ciel.'

"The rock-salt is of different colours, but blue, grey, and yellow are the most common. Frequently it is friable, and sometimes slaty, and peels off in transparent cakes—resembling the tracery work produced on a window by frost. There are often found, in a chamber of 613 yards in circumference, seven or eight masses of slaty rock three or four feet in diameter, which do not contain any salt whatever. Of course these masses resist the direct action of water, but, as all the parts round them containing salt are gradually dissolved, they are in the end detached from the roof and deposited on the floor. We saw several of these in one of the chambers we examined. The water had been drained out of this chamber three weeks before, and it was illuminated with about fifty candles. One of these masses, like a shapeless column. reached from the floor to the ceiling;

some, on being detached, had left cavities two or three feet deep, and several were still suspended. The miners pass carelessly under them. But that which caused me most alarm was to find myself under a ceiling 584 yards in circumference, on which the weight of the superincumbent mountain rested, and which was not even supported by the vaulted form which nature usually gives to the roofs of subterranean caverns. It was perfectly flat, and was only sustained by the adhesive forces which existed between all the various parts of this immense apartment. The firmness thus occasioned is so great, that only one instance has occurred during several centuries of a ceiling having given way.

"There are thirty-six chambers excavated in the mountain. They are partly shaped by the action of the water, and their dimensions are irregular, according as the mass composing the roof or walls is more or less charged with salt. Many chambers are excavated one over the other, thus forming different stories, the mass which separates one chamber from another serving the same purpose as boards and lath and plaster in houses, though of course much thicker. The miners informed us, while we were examining one chamber, that above us was a chamber at that time filled with water. It may appear singular that a large body of water thus situated should not find its way into the apartment beneath, but we found the ceiling scarcely humid. The reason of this is, that before the water is introduced, the floor is covered with clay, which is beaten down so as to render the surface impervious to the water. A kind of blue clay is used for this purpose, which is worked up into a proper consistence with wooden mallets; and when it no longer contains any rough particles it is spread over the floor. If it should leak, a little saw-dust is thrown into the water, and by this means the position of the outlet is ascertained, which is first of all enlarged, and then securely plugged with the clay cement. If the water escapes by one of the galleries, the gallery is abandoned to a certain distance, and endeavours are made with the cement to repress the passage of the water as much as possible. If this fails, however, it becomes necessary to open another gallery, and this is the most difficult task which the miners are called upon to perform. In executing this work they are obliged to divest themselves of every article of dress; as, without this precaution, their clothing would absorb a strong saline composition, which would render it hard and brittle, and cause it to tear the skin. I could not think without compassion of these unfortunate men being thus employed for nine hours a-day for so small a recompense as twelve kreutzers (4*d.* or 4½*d.*). The men are relieved every three or four hours when thus occupied; and from the hardships they undergo they are not long-lived.

"When the water in the chambers is sufficiently impregnated, it is drawn off. When it is entirely withdrawn, the ceiling is found to have increased about two feet in height; but at the same time the floor is raised two feet by the fallen materials. By this means the necessary degree of thickness is maintained between one chamber and another. Two chambers situated one above another are by this process in a gradual course of ascension, so that the lower one occupies the same elevation in about eight or nine years, which was previously held by the one above it. The saline matter, of which the ceiling is composed, is dissolved, and the other parts are deposited on the floors. The materials thus deposited, although destitute of any saline particles, in the course of time acquire the qualities of rock-salt,—a process which promises to render the mountain at Hallein a perpetual source of riches.

"Care is always taken that two neighbouring chambers are not placed on the same level, as the lateral pressure of the water might open a communication between them. When a chamber has been made use of, it is necessary to raise the gallery leading to it, the deposits which have taken place having made the floor about two feet higher than before. On this account a chamber is only used once in three years.

"A remarkable instance of the growth of a saline rock may be seen at Hallein. In forty years it has encroached about three feet on each side of the gallery, a wooden trough, which runs through the centre, offering a resistance to it in that part which it has been unable to overcome. Each of the galleries, and the aperture by which it is entered, has its separate name, as well as each chamber. The gallery named Wolf Diedrich is so called after one of the prelates who filled the archiepiscopal see of Salzburg, a man of great firmness of character and strength of purpose, as will be seen by the following account of the Wolf Diedrich gallery, which was dug in a part of the mountain which had not previously been penetrated. This gallery was absolutely necessary as an outlet to the water after it had become impregnated with salt, but the only side of the mountain on which it could be executed consisted of the hardest description of marble or granite, and, according to the plan of Wolf Diedrich, it was necessary to penetrate through 1578 yards of this material. Objections were made on the ground of the expense of such an undertaking, and its probable impracticability; but he persisted in spite of these unfavourable opinions. The ordinary implements being found of a temper too soft for the purpose, he caused them to be made of steel, but still they only struck from the rock particles as small as dust. Wolf Diedrich hoped with all the strength of perseverance. 'If we only succeed in obtaining dust,' he said, 'we shall in time penetrate into the heart of the mountain.' The work was carried on in opposite directions, one party commencing on the outside of the mountain, and the other in its interior, and was continued in this manner during fifty years. The mountain engineers who directed the labours of the workmen, guided their course with such precision, that the two passages opened into each other at the place appointed for their junction. There was, however, some error in the levelling, arising from their having neglected the rules on which they had at first proceeded, and being guided, on the near termination of the work, by the sound of their tools. The sound deceived them, and the error which they made is still visible. This gallery is about a yard broad, and nearly five feet high. It is divided into sixteen stations, where recesses are made, into which, when two *wursts* meet, one of them can be withdrawn to allow room for the other to pass. The inclination of the gallery is about an inch in two yards.

"We were afterwards conducted into a chamber, the walls, floor, and ceiling of which consisted entirely of salt. Fifteen of us entered this apartment, the appearance of which, when illuminated by our torches, was very extraordinary. This is a sort of council-chamber of the miners, where the superintendents are received when they pay their annual visit.

" The following is the extent of the mine:—length 2012 yards; depth 314 yards. The expenses of maintaining it in a proper state for working are not great, owing chiefly to the wood which is made use of becoming so thoroughly impregnated with salt as not to require renewal. The pernicious gases which are found in coal and other pits are occasionally generated in these works, but not to such an extent as to produce disastrous consequences. The water at times occasions considerable damage.

" We spent three hours in the heart of the mountain; the air is neither hot nor cold, but of a mild and equable temperature. We proceeded out of the mine by the marble gallery of Wolf Diedrich, seated on a *wurst* drawn by the miners."

From the following description it will be seen that there is an efficacious mode of obtaining salt from salt-water, by evaporation produced through the agency of artificial heat. In Scotland this method has been pursued from a very remote period, and to an extent probably unequalled in any other country. Records are still in existence attesting the endowment of abbeys with salt-pans, some of them referring to a period as early as the twelfth century: the abbey of Holyrood, for instance, was endowed by David I. with the salt-pan of Airth, near the head of the Frith of Forth, along the shores of which noble river the chief salt-pans are still found. The mode of manufacture is said to have been greatly improved during the reign of Mary, Queen of Scotland, by the attendants whom Mary brought with her from France, and who received in consequence an exclusive privilege for the production of the commodity, which was continued until the reign of Charles II. At two different periods the Scottish salt manufacture has received great injury; the first at the time of the Union, when the duties levied in both countries were equalized (the ruins of salt-pans scattered along the whole coast of Fife yet attest the effects of that measure); and the second, when the duties were entirely repealed, a few years ago, in consequence of which many important works were relinquished. We have now to describe the mode of manufacture.

Near the shore, in a suitable spot, is erected a long and low building, divided into two parts—the one called the fire-house, intended to shelter the workmen and to contain the fuel required; the other, known as the boiling-house, fitted for the reception of the pan in which the brine is contained during evaporation, and for the furnace below. The pan is of an oblong form, commonly measuring about fifteen feet in length, twelve in breadth, and in depth about fifteen inches. The material is generally wrought-iron, but the sides are sometimes of lead, as the iron is apt to oxidize. A walk five or six feet in breadth extends on each side of the pan for the accommodation of the workmen who assist in the operations. The roof of the saltern (as the building is called), which is partly open to allow of the escape of the steam, is fastened with pegs of wood, as iron nails would quickly be destroyed by the vapour. Near to the saltern is a shed containing the cistern, which is fixed at such a height as to allow the salt water it holds to run through pipes into the pan. The cistern is filled by means of machinery, which pumps up the sea-water from a well communicating by long pipes with a pool or 'lump' in the shore. It is an object with the workmen to draw the water from a point as far below the surface as possible, as they then find it more impregnated with salt, and therefore requiring less trouble, and involving less expense for firing in the process of evaporation. When the sea-water in the cistern has had sufficient time to settle, and deposit its mud and sand, it is allowed to flow into the pan (or pans, for there is generally in the large works a range of them extending on both sides of the cistern), and a strong fire is now lighted in the furnace beneath. As soon as the fluid is lukewarm, it is clarified, either by mixing the white of three or four eggs with two or three gallons of water, and pouring the mixture into the pan, or by means of the blood of sheep or oxen. As the water gets still more heated and approaches to boiling, a frothy scum appears, which is collected into little vessels fixed one at each corner of the pan: after this process, the water speedily becomes clear. Having boiled about four hours, crystals appear on the surface, and the amount of water is seen to be greatly lessened: the pan is now refilled with fresh sea-water, allowed to heat, clarified, and cleared from the scum as before, the whole of the process being exactly repeated, and the same a third and a fourth time: after this the pan is no longer supplied with fresh water, the fire is slackened, and, at the end of ten or twelve hours, a large quantity of salt is found nearly dry at the bottom of the pan. This is now raked together into one or two heaps, in order that the brine may drain off; next it is conveyed in barrows to the store-rooms, and laid in 'drabs,' or wooden troughs with shelving bottoms, to allow what little moisture remains to drain away, and from which it is taken, in three or four days, perfectly fitted for immediate use. Each pan of salt requires in the making about twenty-four hours in the whole, so that only five pans a week can be made. The furnaces, however, are never permitted to cool: when the workmen are about to leave on the Saturday afternoon, they place a small quantity of brine in the pan, which is left to simmer, without attendance, till Monday morning; and the product is the Sunday salt, which is in such great request in some parts of Scotland, as being much finer than the ordinary 'every-day' salt. The fuel used is small coal, which, by a curious incongruity, is called wood: the origin of this custom may in all probability be traced to a period when wood alone was used. Two men attend each salt-pan, one of whom is a sort of drudge to the other. These people are a very peculiar race. In appearance and manners they are not unlike colliers, whom too they resemble in another point, their former state of slavery. Till within the last fifty years or so, the salters were transferred with the works on any change of property, in as positive a manner as the black population in our own colonies prior to the late changes, or as the American slaves at this moment. Their freedom was obtained by an application of the proprietors themselves, a rare and honourable action; but so little did the salters themselves appreciate it, that they exclaimed against the whole affair as nothing more than a petty attempt on the part of the proprietors to relieve themselves of a trifling burden to which they are liable on the marriage of a salter or coalman! We conclude with observing that a great proportion of the salt thus prepared is carried by women, chiefly the wives and other relatives of the salters, to Edinburgh.

From an account published in the 'Penny Magazine' a few years ago, by a writer who had personally witnessed the operations, it will be seen that the "salt-licks" of America differ in character from both the saline sources hitherto described.

Salt-lick, although but another name for salt-spring, is the term commonly applied to those weak, and, in many instances, almost imperceptible springs of water, that are more or less impregnated with salt; and which, in some sections of the continent of America, are commonly met with, particularly in hilly districts, and at a considerable distance from the sea. Salt-licks are frequently called deer-licks by the Americans, from their being much frequented by elk and deer. Indeed where these springs are weak, and their channels consequently hidden or lost among the almost endless obstructions that impede an infant stream or brooklet in the rough and rude forests, the well-heads of these salt-springs are commonly ascertained by the hunters observing the various deer-tracks leading to one point, whither these animals often repair to browse upon the salt-impregnated herbage (when there happens to be any), or to 'lick' the pebbles at the well-head, or lap the water at the spring. Hence it is that the discovery of a salt-lick by an American hunter is looked upon as a most fortunate circumstance, since it affords him facilities of falling in with and shooting down his game, that are only enjoyed by those who hunt in the vicinity of springs of this nature.

It is generally supposed by those who possess the best means of judging, that salt-springs are more numerous *west* of the extensive range of Alleghany mountains—that is, in the valley of the Ohio, and even through the region west of *that*—than they are to the eastward of the aforesaid mountains, or in a district of country comparatively near to the ocean; and in this it is not difficult to detect the hand of an all-wise governing Providence that hath ordained all things for the best.

The most copious salt-springs that have yet been discovered, or rather that have been rendered available to useful purposes, are those near the young and flourishing town of Onandaga, in the northern part of the state of New York, rather more than 30 miles north-east of Lake Ontario, and nearly 300 from the Atlantic Ocean. For thirty years these springs have yielded considerable quantities of salt; and the salt-works established there are, in fact, the only extensive and very productive ones throughout the United States. Before these works were in successful operation, and at a period when there were neither canals nor roads through this section of country, salt was a scarce and dear article in all the new settlements situated to the westward; but now that inland communications have been opened, connecting one part of the western country with another, and hence with the older settlements, a barrel of salt weighing 280 lbs. can be purchased on the shores of Lake Huron or Michigan for a sum not exceeding ten shillings sterling. It may be as well to remark that the salt-springs above alluded to are situated in a part of the country by no means mountainous, although somewhat hilly and broken, and at an elevation of a few hundred feet above the level of the sea.

Where salt-licks or weak springs of salt water are known to exist, the owner of such lands (and here the forest is alluded to, where the lands are in a wild state) will sometimes expend considerable sums in boring for salt, apparently upon the supposition that the salt water, which already finds its way to the surface, issues, in all probability, from some capacious reservoir, which, if he could but reach it by boring, might yield a plentiful and never-failing supply.

The process usually adopted by the Americans in boring for salt is somewhat ingenious. Having fixed upon the place where the parties intend to bore, commonly adjacent to the lick or spring, they commence making a perpendicular hole with an instrument called an auger, being shaped exactly like those used by miners in perforating the rocks for the purpose of blasting them, but the diameter being greater, generally about two and a quarter inches. The iron part of the auger, the end of which is faced with steel and brought to a blunt edge, is from three to four feet long, and made in such a manner that a wooden pole of equal diameter can be securely attached to it, in order to give it the desirable length as the work progresses. When the hole has been bored to a moderate depth, a stout upright post with a forked top is firmly fixed in the ground, in the fork of which a long straight pole is placed, where it acts as a lever, this being the principal part of the machinery used in boring. One end of this lever is placed directly over the hole, for the purpose of its being brought down and attached to the upper end of the auger or 'borer,' when, by depressing the contrary extremity of the lever, the auger is raised to the height desired, and by the pulling of a small cord when it is so raised, it instantly becomes detached, and descends into the auger-hole with considerable force. As the depth of the hole increases, other pieces of timber, of suitable size and length, are attached to the 'borer;' and in this way the work is carried on until the necessary depth is attained. One person stands over the hole, whose duty it is to turn the borer one-third or one-half round every time it is raised; a second manages the long lever, and a boy pulls the cord, by which means the borer slips from the end of the elevated lever. In perforating hard rocks, this method of boring is slow work; and as occasional changes of augers, for the purpose of re-sharpening, become necessary, a great deal of trouble is occasioned every time this takes place after the boring has reached the depth of two or three hundred feet, when all the intermediate joinings of the wooden part of the borer have to be undone. These borings are undertaken with the view of reaching some larger or purer body of salt water than that which rises to the surface; and although not generally successful, there are instances where large reservoirs (apparently) have been reached, from which ever afterwards a plentiful supply has risen through the aperture to the surface. These borings are never made with the view of afterwards sinking a shaft; but should water of sufficient saltness be discovered, thin tubes of tin or copper, of the requisite diameter, are inserted in the hole as a *lining*, for the two-fold purpose of keeping the hole open, and the water of such springs as may lie between the salt one and the surface of the earth from mingling with, and thereby decreasing the quality of, that which is intended to be turned to a profitable account.

CHAPTER III.

ON SULPHURIC ACID; SODA; CARBONATE OF SODA; MURIATIC ACID; CHLORINE; BLEACHING-POWDER; AND ALUM—AS PRODUCED MAINLY FROM SULPHUR AND SALT.

Thus, then, we see that sulphur and salt are two of the abundant gifts of nature, which by a few simple operations man brings into a form practically serviceable to him in every-day life. Let us now see how, from these and a few other ingredients equally simple, some of the important chemical commodities are produced.

Sulphuric acid is the first of these which may be noticed. This acid is composed of sulphur and oxygen; and the principle of the manufacture rests on the abstraction of oxygen from the atmosphere, under circumstances which enable it to combine with common sulphur; and all the arrangements of the sulphuric acid factories are conformable with this object. The greater part of the sulphur so employed comes from Sicily, because, unless commercial tariffs and restrictions interfere with its natural price, it can be obtained thence cheaper than from our own mineral districts; but if any circumstances should render the price of Sicilian sulphurs too high, means are adopted by our manufacturers for extracting sulphur from iron pyrites, a mineral extensively found in England.

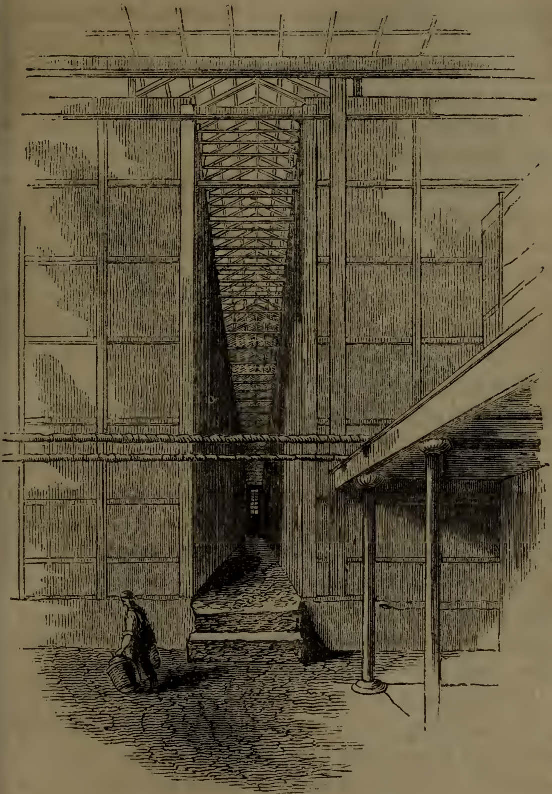
About six years ago the price of Sicilian sulphur was driven up rapidly, through the following circumstance:—The sulphur-mines in that country are the property of individuals; and from fifteen to twenty English firms, settled in Sicily, are engaged in the trade. In 1836 M. Taix laid before the Sicilian government a project for establishing a company which was to have the exclusive right, during ten years, of purchasing Sicilian sulphur at fixed prices on certain conditions. The British merchants becoming alarmed, the Sicilian government gave deceptive assurances, but persisted in their plan; and on July 4th, 1838, notice was given at Palermo that the monopoly would come into operation on the 1st of August ensuing. The negociations respecting this monopoly were conducted with great secrecy; and it came into operation so suddenly that twenty-four vessels lost their cargoes. The British lessees of mines, and all others, were compelled to produce only a fixed quantity of sulphur; prices rose from 6*l.* 10*s.* or 7*l.* to 13*l.* and 14*l.* per ton, and contracts could not be completed. Previous to the monopoly, 484 British vessels sailed from the ports of Sicily to the United Kingdom; but in the first fifteen months after the monopoly the number was only 157. At length the British government took very decided steps to put an end to a monopoly established in the face of commercial treaties: the coasts of Sicily and Naples were blockaded by our ships of war, and the Sicilian government, no longer daring to uphold the monopoly, accepted the mediation of the King of the French in adjusting the dispute with the British government. After this, the trade resumed its former channel.

In many of the sulphuric acid works are ranges of upright furnaces, adapted for the extraction of sulphur from iron pyrites, in case such occurrences as these should again interfere with the sulphur-trade. Into these furnaces is placed the pyrites, a mineral containing rather more than half its weight of sulphur, and rather less than half iron; and by a careful series of processes, a large percentage of the sulphur is obtained in a form fit for the manufacturer of sulphuric acid. But at the present time the price of Sicilian sulphur is sufficiently low to render the adoption of the English mineral unnecessary. This is one of the points to which we referred in illustration of the intimate connection between commercial legislation and chemical manufacture.

The Sicilian sulphur is brought over to this country 'in bulk,' that is, stowed away in the hold of the ship. It is prepared at the Sicilian sulphur-works in masses weighing about half a ton each; and these masses generally become broken into small rubble or fragments by the time they reach the English chemical works. So enormously has the use of this commodity increased in England, that whereas five thousand tons were used in 1820, ten times that quantity is now used annually; and we import, in fact, more than half of all the sulphur produced in Sicily.

We will suppose that a heap of sulphur lies in one of the warehouses of a large chemical work, ready to be operated on in the manufacture of sulphuric acid. In a furnace-room are numerous furnaces for burning the sulphur, arranged on each side of a hollow wall, through which the gaseous products ascend into large vessels. Every one knows that sulphur will kindle very readily, and it is equally well known that a very suffocating gas accompanies the blue flame resulting from the ignition. This gas is sulphurous acid, and the object of the manufacturer is to collect it carefully. The furnaces are a kind of flat quadrangular chest, measuring about seven feet by five; they are made of iron, and are capable of being closed-in perfectly or nearly air-tight. There is a door in the front of each furnace, through which is introduced about a hundred pounds of sulphur at a time; the sulphur is kindled, the door is closed (leaving a narrow aperture for the entrance of the air required to support the combustion), and in about two or three hours the whole of the sulphur, except a very small residue or ash, is converted into sulphurous acid vapour, which ascends the hollow wall to fitting receptacles. If one of the doors be opened, we can see the lambent blue flame from the burning sulphur, and become sensible of the well-known odour resulting from the combustion.

The sulphurous acid gas passes from these burners or furnaces into vessels so vast that it is difficult to estimate them by a common standard. Brewers' vats, 'Heidelberg tuns,' all sink into insignificance when compared with these vessels. In one particular factory there are two such vessels, each nearly two hundred feet in length, twenty in width, and twenty in height; and four others about half this length. They are not sunken tanks or cisterns, but vessels erected on the ground, formed of sheet-lead, and held together by appropriate frame-work. There are avenues between the vessels, or 'chambers,' as they are called; and nothing less than a walk from one end to the other of one of these avenues (such as is slightly sketched in the adjoining cut) can convey an adequate idea of the dimensions.



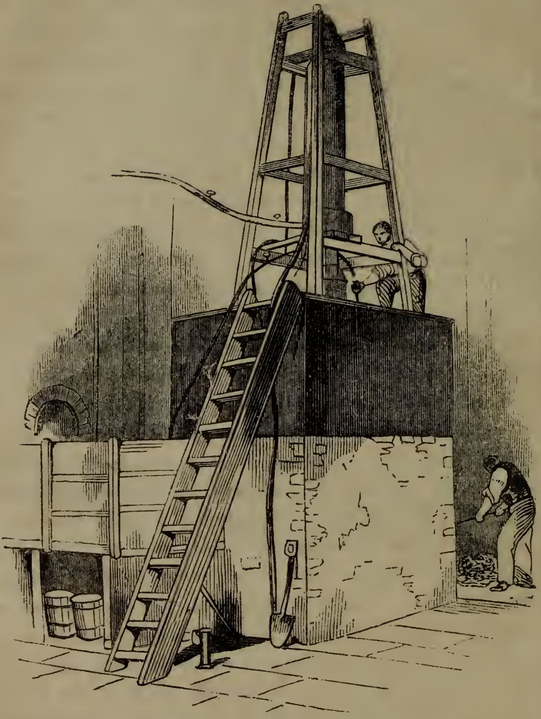
[Sulphuric-acid Chambers.]

Into these chambers the gas passes; but not alone: there are some beautiful chemical changes involved before the gaseous sulphur*ous* acid can be converted into liquid sulphur*ic* acid. The latter contains a little more oxygen than the former, for the same amount of sulphur; and a curious agency is employed for the supply of this additional portion. Into the sulphur-furnace is introduced a little nitrate of soda, placed in a dish on a stand above the burning sulphur: the heat from the sulphur occasions the evolution of nitrous-acid vapour from the contents of this dish; and this vapour enters the leaden chambers in company with the sulphurous-acid vapour. The two gases will not exert any particular effect on each other while in this condition; but if moisture be present, an action immediately commences. There is a steam-boiler arranged near the chambers, from which a supply of steam is obtained; and this steam, flowing into the chambers with the two gases, effects a transference of oxygen from the one to the other. The sulphur*ous* acid only requires a little further supply of oxygen to transform it into sulphur*ic* acid; and this supply it obtains from the atmospheric air (which enters with it for the purpose) by the agency of the nitrous-acid gas and the steam. Sulphuric acid is not a gas; it combines with the water of the steam, and accumulates at the bottom of the leaden chambers, from whence it is drawn off at stated intervals.

The chemical niceties involved in many parts of this process are very great; but into these we need not enter. Suffice it to say that from tasteless sulphur, from the salubrious oxygen which we breathe, and from common steam, are produced the hot and burning sulphuric acid, or oil of vitriol, in the form of a very dense liquid. This liquid falls into tanks, from whence it is pumped or forced up into other vessels, to be either sold in that state or to be concentrated to a greater degree of strength. Such is the corroding nature of this acid, that few metals are found capable of resisting it; and on that account lead is extensively employed in the manufacture, this being one of the exceptions. For instance, the fumes pass through a large leaden pipe; the chambers are of sheet-lead; and the liquid acid falls into a leaden tank.

Few things are more remarkable in the manufacture than the enormous expense which this corroding tendency has entailed on manufacturers of this acid. In order to give a higher degree of concentration to the acid, it is distilled by the agency of heat; but lead will not bear this heat, and other common metals will not bear the action of the acid. Under these circumstances the stills are made either of glass or platinum. When glass stills are used, they are heated by means of hot sand, into a bed of which they are placed; but breakages so frequently occur, that the use of platinum has almost superseded glass for this purpose. Platinum is a metal which will resist the action of nearly all acids; and as it will also bear a most intense heat, it is invaluable for such purposes as these. But it is procurable in such small quantities, and is brought into a marketable form with so much difficulty, that its commercial value is enormous. For concentrating the sulphuric acid at some of the works, platinum stills are used, which have cost several thousand guineas each, the value of the metal being several times as much as that of pure silver! As the costly metal is made no thicker than is absolutely necessary, the portion of it exposed to the fire is protected by an iron casing.

It does not form part of our object here to describe



[Platinum Still, for concentrating Sulphuric Acid.]

manufactures in metal; but a few words may be introduced explanatory of the reasons why the production of platinum vessels is a difficult and tedious process. As the metal cannot be procured naturally in large masses, and as the heat of furnaces will not melt it, it is brought into workable form in an extraordinary manner, first developed by Dr. Wollaston. It is found in the metallic state, in small grains, mingled with grains of many other metals. The other metals are removed from it by chemical means, and the platinum is then presented in the form of small grains. These grains are crushed in a wooden mortar with a wooden pestle, to the state of powder, which powder is brought to a pasty form with water. The paste is put into a small ingot-mould, and pressed very powerfully by an appropriate machine, by which it is compacted into a solid form, the grains of powder cohering by a sort of welding property. This ingot is placed upon a charcoal fire, to drive away the remaining moisture; it is next exposed to the fiercest heat which furnaces can give, to remove every other extraneous substance from it; it is next hammered in particular directions, to give it a temper and toughness; and is then in the form of a small solid piece, fit to be rolled and forged into sheets, or any other practicable form. All this labour, bestowed upon a small bar only six or seven inches long, necessarily makes the manufactured article very costly.

After the acid has been concentrated to a density not much less than double that of water, it is cooled, and finally packed in large glass carboys enclosed in osier baskets.

As there do not appear, in common life, to be very many uses for sulphuric acid on a large scale, it may seem strange why such vast quantities should be made; since a large portion of all the sulphur imported is used in making this acid, and the acid produced is nearly three times as great in weight as the sulphur employed. But (as was before observed) it is as an agent in producing many other important chemical substances that this acid is so largely used; and to some of these attention may next be directed.

Soda, a substance so largely employed in glass-making, in soap-making, in bleaching, in washing, and in many other operations, is at the present day produced by the application of sulphuric acid to common salt; and the manufacture is one of those carried on at many of the large chemical works. Most remarkable have been the changes in the mode of producing this useful alkali. Some years ago the duty on salt (now employed in the manufacture) was almost unprecedentedly high: it amounted to 30*l.* per ton; whereas the commodity can at the present day be purchased for ten or twelve shillings per ton: that is, the duty was once fifty or sixty times as great as the article itself can now be actually bought for! Under these circumstances, the production of soda from this substance was not thought of commercially. At that time the soda was prepared from *kelp*, a kind of sea-weed found on the shores of the Scottish Highlands and Islands; in a manner which we shall notice when speaking of the soap-manufacture. *Barilla*, obtained from the ash of an Italian sea-weed, was also employed for the same purpose. But common rock-salt has now nearly superseded the latter, and wholly so the former. Indeed so marked has been the change, that though the commercial and manufacturing advantages have been immense, the result has been in some respects painful, since the Highlanders who used to be employed in the kelp manufacture are now wholly deprived of that source of income.

Common salt is chemically designated chloride of sodium; common soda is chemically carbonate of soda; and the process of manufacture consists in separating the sodium from the chlorine, and making it the chief element in a new compound. It instructively illustrates the way in which one chemical process necessarily involves another—that the very same operation which leads to the production of carbonate of soda from one element of the salt, leads to the production of muriatic acid from the other. So rapidly has this branch of manufacture extended, that it was estimated in 1838 that more than seventy thousand tons of carbonate of soda were made from common salt in that year.

On entering those parts of a chemical factory where the soda process is carried on, the peculiar odour of muriatic acid is very perceptible, different from that diffused throughout the other buildings. The rock-salt is procured from the vast beds at Northwich in Cheshire. It is exposed to various processes, by which the chloride of sodium is converted into a sulphate of soda; then this into what is called ball-soda; then this into the soda-ash employed in making soap and glass; and, lastly, this into the crystallized soda of the shops. Throughout these operations a succession of chemical changes ensues, not less remarkable than those in relation to sulphuric acid.

A given weight of salt is placed in a reverberatory furnace, that is, one in which the heat is echoed or reflected down from a concave roof upon the ingredients in the furnace. The salt is placed in a leaden pan within the furnace, and sulphuric acid is let down upon it through a leaden pipe in the roof of the furnace; or rather, the decomposition is first partially effected in an iron pan heated below, and then finished in the reverberatory furnace. The salt liquefies in the acid ; and the heat which is brought to bear on the mixture soon causes a gaseous vapour to ascend. This gas is muriatic-acid gas, containing, as one of its ingredients, the chlorine which had before been in the salt. The muriatic acid thus produced has often been a source of great trouble and expense to manufacturers. It is so deleterious, that if allowed to mingle with the atmosphere near the ground it would do great mischief; and hence the giant chimneys which such works exhibit, intended to carry off the gas to a great height. The gas, however, is now, in some of the factories, converted to a liquid form by an ingenious arrangement. All the furnaces discharge their muriatic-acid gas into a bulky stone tower, about forty feet high by eight feet square. This tower is filled with coke, upon which a stream of water is constantly falling from above ; and the gas, ascending the tower from the flues of the furnaces, meeting with an innumerable series of little streams of water trickling through the coke, becomes absorbed by the water, and falls again in the form of liquid muriatic acid. Thus a double advantage is gained by this plan : the muriatic acid is preserved in a form which renders it available for other departments of manufacture ; and the atmosphere is saved from admixture with this most deleterious ingredient.

Meanwhile the salt has greatly altered its form. When the muriatic acid, by the application of heat, and by frequent stirring, has been removed from the furnace, the pasty mass which remains is sulphate of soda ; and this sulphate is, at a particular period, drawn out of the furnace in a dry state.

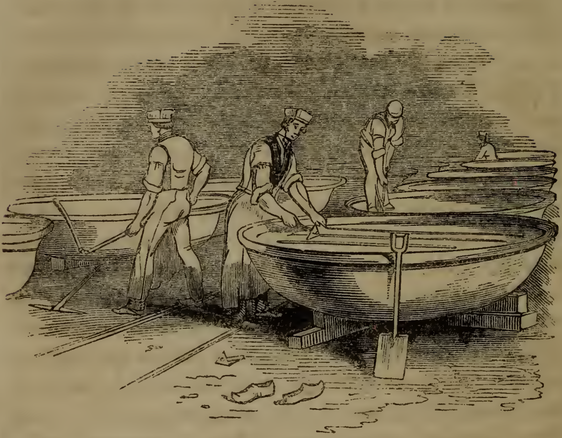
Then ensues another process, in which the chemical changes are too complex to be minutely detailed here, but whose general character may be pretty clearly explained. Furnaces of a peculiar form are provided, called *balling furnaces*, for the conversion of sulphate of soda into ball-soda. The sulphate is mixed up with chalk or lime, and with coal, both ground very fine at a mill; and the whole are sifted to the state of powder before being put into the furnaces. When the mixed powder becomes heated, the coaly portion ignites at the surface; and when the mass begins to become liquid, a workman opens a door in the front of the furnace, introduces a rake or shovel, and turns the mass over, so as to expose a new surface uppermost. The door is again closed; the heat is allowed to act on the mass; and little jets of flame then begin to burst from it in every part. The workman next stirs and spreads the semi-fluid mass in every direction; and at length he removes it from the furnace. This is a very pretty operation—at least it may be regarded so by a bystander, although it is rather a warm one to the workman himself. A low four-wheeled iron carriage is wheeled to the front of the furnace; on this carriage a shallow tray is placed, and into this tray the workman draws the semi-fluid mass from the furnace, by means of a kind of rake introduced at the door of the furnace. Shortly after the mass has fallen into the carriage, innumerable little jets of flame, called by the workmen "candles," burst out at its surface, and present a curious miniature illumination.

The semi-fluid mass solidifies in the iron tray, and comes out as a square mass, measuring about three feet square by one in thickness. This is called ball-soda, or crude soda, or British barilla, and is the result of a curious series of chemical changes. The matters put into the furnace were coal, lime, and sulphate of soda; and these elements become so mingled and transferred by heat, that they appear, in the ball-soda, chiefly as carbonate of soda and sulphuret of calcium.

Next ensues the separation of the two ingredients just named: the former valuable, and indeed the object of the whole operation; the latter valueless up to the present time. The ball-soda is put into a cistern or tank, and covered with water, which is allowed to act on it for a considerable time, as a means of dissolving the carbonate of soda. The liquor is drawn off at the bottom, and more applied; and so on until all the carbonate has been dissolved. The point here aimed at is to dissolve all the carbonate and none of the sulphuret, for the latter would spoil the former. When this is accomplished, the liquor containing the dissolved carbonate is placed in an evaporating furnace, where, by the application of heat at the surface of the liquid, all the watery part is caused to evaporate; and the solid which remains is chiefly carbonate of soda, with a very small admixture of sulphur. By a further exposure to the heat of a furnace, this sulphur is driven off; and there remains a yellowish earthy substance, which is the common soda-ash or soda-salt, employed extensively in various manufactures. It contains about fifty per cent. of pure soda.

One more stage of improvement occurs before the soda is finally completed. For some purposes this earthy carbonate of soda will not suffice: it must be in a crystallized form; and to effect this crystallization another series of buildings, of processes, and of vessels is necessary. The soda-ash is again dissolved in water, again allowed to settle, and then boiled to a certain degree of consistency. Next ensues the crystallization, which is one of the most striking features in such operations. In a very large and cool building are numerous hemispherical cast-iron vessels, from five to ten feet in diameter. In these the liquor is placed, after having deposited its solid impurities; and here it remains until all that will crystallize has done so. It is a beautiful sight to see the large crystals radiating from the sides of the vessels towards the centre, and absorbing, as it were, into their substance more and more of the liquor, until only a little of this latter remains. After several days, the crystals are broken out from the vessels, to be packed in barrels for the market; while the remaining liquid, called the 'mother-liquor,' by a further process of evaporation, yields a very coarse kind of soda, fitted for some manufacturing purposes,—thus adding one more to the forms in which soda is presented by this interesting chain of processes.

One thing has yet to be noticed. What becomes of the solid impurities which occur in the process? This is one of the difficulties to which a chemical manufacturer is exposed. The sulphuret of calcium, the solid and useless ingredient in the ball-soda, is a veritable source of trouble and expense. No profitable mode of applying it has yet been introduced: it cannot be melted and washed away, or heated and burned away; nor must it be thrown into any river. At one of the great soda-works an enormous heap of 'waste' has accumulated, covering an area five or six acres in extent, and mounting to a height of thirty or forty feet. Day by day is this heap increasing in extent; and more land has lately had to be purchased,



[Soda-crystallizing Pans.]

to form a resting-place for heaps yet to accumulate. The earthen waste is not thrown here heedlessly: it is laid in a compact form, having a smooth and level surface at the top; and if the memory of present things were to pass away, future geologists might be puzzled to conjecture how such a mound got there. Not only the sulphuret of calcium from the soda process, but silica and ashes from other processes help to swell this heap.

Bleaching-powder.—Another curious result of the extensive use of sulphur and common salt in manufactures is the production of *chlorine* and *bleaching-powder*, frequently carried on at the sulphuric acid and soda works. Bleaching-powder is chemically called chloride of lime; but its most marked property has given it the former distinctive name.

Here also we have another example of the influence which legislative matters exert upon chemical manufactures. If the duty had not been taken off common salt, it may be safely averred that the manufacture of these articles would not have reached its present height. Salt not only yields soda from one of its constituents, and muriatic acid from the other, but this acid itself is made to yield chlorine, by separating hydrogen from it. Chlorine is a gas, and as such is not in a convenient form for sale and commercial transit; but by causing it to be absorbed by any dry and cheap substance, such as lime, it can be brought into a convenient form. Such is the case in practice. Chloride of lime is now used to an immense extent in different branches of manufacture, the lime being merely a vehicle for containing the chlorine, and all the remarkable chemical effect being due to the latter.

Chlorine requires for its production or evolution a degree of care in the choice of vessels, analogous to that exhibited in so many other branches of chemical manufacture. The chief vessels employed are made of stone contained withinside iron vessels; and into the innermost vessels are put the necessary ingredients. These are muriatic acid and oxide of manganese. Steam is admitted between the inner and outer vessels, by which the mixture is raised to the required temperature; and by the mutual action of the chemical ingredients they become so altered in their combinations as to produce muriate of manganese, water, and chlorine gas, the last named of which is the object of the manufacture. In this process, and in the subsequent one of causing the chlorine to be absorbed by lime, the most scrupulous precautions are taken to prevent the escape of any of the gas into the open air; since it is so deadly a poison, that the inhalation of a very small portion of it would suffice to take away life. Some years ago, when the muriatic-acid gas was allowed to go to waste up the chimneys of sulphuric acid works, chlorine was produced from sulphuric acid, salt, and the oxide of manganese; but the muriatic acid is now economically used instead of the sulphuric acid and the salt—thus at once cheapening the product and saving the atmosphere from contamination.

The mode of impregnating lime with the gas is very curious. A chamber is fitted up in the most completely air-tight manner, with a few openings carefully secured. On shelves in this chamber is deposited slaked lime in powder, spread out so as to allow the chlorine to act upon it. The gas, as it escapes from the vessels, flows through a pipe into this chamber, which it gradually fills; and as soon as it comes in contact with the lime, the two substances unite, forming chloride of lime, by which the whole of the gaseous element is absorbed.

This powerful agent is in a most convenient form for manufactures. When the chloride of lime is immersed in water, it dissolves, and the water becomes impregnated with the chlorine, which then forms the bleaching-liquid now so largely used in the manufacturing districts. About a century ago our manufacturers of linen used to send their cloths to Holland to be bleached, where they were steeped in potash ley, then washed, then steeped in buttermilk, and then laid out on the grass for several months; so that the linen was thus out of the maker's hands for seven or eight months before he could bring it into the market. A process very similar next became established in this country; the goods being still several months under process of bleaching, but the transference to and from Holland being no longer necessary. Next sprang up an improvement by the substitution of sulphuric acid for milk, whereby the same effect was wrought in one day which before occupied six weeks, and brought the whole bleaching process within a period of three or four months. Next ensued the discovery that a particular gas, evolved by the action of manganese on muriatic acid, had the power of destroying vegetable colours, or of bleaching; and about sixty years ago, Berthollet practically applied this new gas (chlorine) in bleaching. Next followed the introduction of this method into England and Scotland, and the institution of experiments for facilitating the use of the gas in bleaching-establishments. If used as a gas, the effects were highly deleterious to the workmen; if absorbed by water, the water gave out a very offensive odour. Potash was added to the chlorine water, to remove the smell; next, the cloth was passed through lime-water previously to the application of the chlorine; and next, Mr. Tennant, of Glasgow, contrived the means of making a liquid chloride of lime, which was the opening to a field of vast importance. One more step was the devising a mode of producing a *dry* chloride of lime which should be capable of being easily packed in barrels, which should retain all the bleaching properties of the chlorine without its offensive odour, and which should be procurable at a cheap rate. This has been done; and the chloride of lime of modern times is presented to us as one of the most successful instances of chemical science applied to manufactures. Instead of eight months, a period of a few hours only is now necessary for the process of bleaching. Dr. Thomson states, "A bleacher in Lancashire received fourteen hundred pieces of grey muslin on a Tuesday, which on the Thursday immediately following were returned bleached to the manufacturer, at the distance of sixteen miles, and they were packed up and sent off on that very day to a foreign market. The quick return of capital which is thus made is a benefit entirely to be ascribed to the new mode of bleaching."

Alum.—Here we have another valuable article, curiously dependent for its production on the agency of sulphuric acid, either naturally or artificially; and its production involves many features well worthy of attention.

It will be well at once to anticipate the question, What is Alum?—and to give an answer to it. We know that, externally, alum presents the appearance of a whitish crystalline substance; but there is nothing to indicate to the eye that this substance is formed of the three singularly opposite ingredients—sulphuric acid, clay, and potash. Yet such is the case; and we here have one of the many startling facts which chemistry presents. In chemical language, alum is a "sulphate of alumina and potash" (soda or ammonia being sometimes substituted for potash); the alumina is the basis or foundation for all varieties of clay, and derives its name from being an invariable ingredient in alum. Dense and opaque as clay is known to be, even in its pure state of alumina, yet it contributes to the formation of the transparent alum so familiar to us.

These, then, being the three ingredients, the next question naturally would be—Are they met with in a combined state, or do they require to be mixed artificially? Both are true; nay there are even four modes of union:

for in some cases crystals of alum are found ready formed in the earth—in others, the three ingredients are met with in the same ore, but not combined into alum—in others, part only of the crude ingredients is found in the ore, and requires the addition of the rest—and in others, the whole are combined by artificial means. The subject of alum-making becomes thus a somewhat complex one; but we may perhaps manage to obtain a few general ideas on the matter, without involving the niceties of chemical detail. As respects native alum, it has been found in the form of crystalline needles in some part of the Andes of South America; in the form of a kind of earthy alum, met with in another part of the same chain of mountains; in the form of long thin fibres, having soda instead of potash, and occurring in a third district of the Andes; and in the form of a mineral called *aluminite*, found in some parts of Germany. In all these cases the ingredients are found combined into a state nearly analogous to alum. To go to the opposite extreme, we find that in France—and also at Newcastle—the alum is wholly an artificial product, formed by mixing clay, sulphuric acid, and potash, so as to lead to chemical combination.

The intermediate modes of formation, that is, those which are in part natural and in part artificial, are of more extensive occurrence; in Italy, in Hungary, in Sweden, in Scotland, and in Yorkshire, we find examples. Various ores or earths, called *alum-stone*, *alum-slate*, *slate-clay*, and *bituminous shale*, furnish the main material; and these, treated in various ways, yield the greater part of the alum of commerce. For instance, at Tolfa in Italy alum is made from alum-stone. Nearly four centuries ago a Genoese merchant, who had seen alum-ore in Turkey, observed that at Tolfa trees were growing such as he had seen near the alum-pits in Turkey; and he thence conjectured that alum-ore might exist there. His conjecture was correct, and alum-works were soon established, which have existed ever since. The Tolfa alum-stone contains all the three ingredients, which, after the stone has been roasted, crumbled into powder, and boiled, combine and crystallize in the form of alum, without the addition of any new ingredient. In Sweden the ore employed (containing a little potash) is alum-slate, which, besides roasting, requires the addition of other ingredients before alum can be formed.

In Yorkshire there are three alum-works. In Scotland there are four, two a little northward of Glasgow and two a little southward. The Yorkshire works, which are near Whitby, originated thus :—Sir Thomas Chaloner, who had an estate near Whitby in the time of Charles I., found alum-ore near the coast, and was desirous of working it; but as there was no one in England at that time who understood the art of making alum, he privately engaged men from Tolfa. The Tolfa works, being very profitable, had from the first belonged to the popes, who, like monopolists generally, tried hard to preserve the whole affair to themselves; the workmen who joined Chaloner were threatened with anathemas and excommunications, but all in vain, for the Whitby works soon became flourishing. Chaloner afterwards had a disagreement with Charles I. respecting the works; for the king, after granting him an exclusive patent, sold half the patent to another party, as a means of procuring money; and this is said to have led ultimately to the active part which Chaloner took against the king in parliament. The Whitby district, where these works are established, is a remarkable one. It consists of precipitous cliffs containing alum-slate, bordering on the sea, and stretching to a distance of about thirty miles along the coast of the German Ocean. The alum-slate is covered with ironstone, sandstone, alluvial soil, and a few other matters; and when these are removed, the rock is broken piecemeal by picks and javelins, roasted, evaporated, and otherwise treated so as to yield alum.

There is a firm at Glasgow to whom three out of the four Scotch alum-works belong; viz. two near Campsie, and one near Hurlet. Either one of these will suffice to show the general character of all; but we select the latter as being, from its great extent, well worthy of attention. The Campsie works are situated among the Campsie Hills, a few miles north of Glasgow; while the Hurlet works are a few miles south of Glasgow; both are situated in a partially-exhausted coal district, for reasons which will presently appear.

A pleasant ride of half-a-dozen miles from Glasgow, or a railway trip to Paisley as part of the distance, brings us to an open part of the country whose green fields give but little indication of the burrowing which has gone on beneath them. On arriving near the village of Hurlet, however, here and there streams of smoke are visible, which point out the localities of certain alum, iron, and lime-works; and these indicate that the mineral riches beneath are not confined to one kind alone. The country around is undulated with gentle hills and hollows; but still there is a grassy covering which effectually conceals these underlying beds. It is not till we enter the precincts of any of these works that we find the pits which open up a communication between the world above and the world below; and even there we see little from whence a judgment might be formed of the honeycombed condition of the ground beneath: we must grope, *in propriâ personâ*, through miles of shallow, dark, arched passages, regardless alike of water, mud, coal, and alum, before we can rightly understand the "whereabouts" of the mines.

When within the boundary of the alum-works, we find an extensive area of ground, occupied in part by buildings where the preparation is conducted, in part by open pits where the ore is steeped, and in part by huge heaps of earthy matter either still burning or lying useless after being burned. It is one consequence of the condition in which the ingredients for alum are found in the ore that a large mass of earthy refuse is separated as an incumbrance; and this refuse is accumulated in enormous ridges and hillocks, until taken away to be used for footpaths or in the formation of railroads. There is no large factory, no many-storied building with its various rooms filled with workmen; the buildings being only such as are necessary to enclose the furnaces, the boilers, the tanks, the coolers, and the other vessels required in the process; together with the water-wheels which raise the ore from the pit, and pump liquid from one vessel to another.

In such districts as this, the possession of a mine by no means implies the possession of the ground above it; the two are held by different tenures, and are leased, or may be leased, independently of each other. Nay, not only so; but if the mineral strata beneath comprise more than one kind, each kind may be leased separately, and to a different person from those who lease the rest.

Something of this kind occurs at Hurlet. The property is owned by the Earl of Glasgow and other parties, and the surface-ground is leased off in the usual way; but as there are four kinds of mineral produce beneath—coal, iron, lime, and alum—the lessee of the surface-ground has, as such, no interest in these sources of wealth: other leases are granted, according to the kind of mineral which is to be worked; and thus there may be four or five leases, and as many lessees, co-acting at the same time in one place. For instance, the Hurlet Alum Company rent all the alum found throughout a certain extent of country, but have nothing to do with the iron, the coal, or the lime found in the same pits which yield the alum, those ores being leased to other parties. It thus arises that there may be, and are, different sets of miners at work at one time in the same series of labyrinthine passages, some to collect one kind of material and some another; each party independent of the others, in respect to the contract with the employers, the mode and rate of payment, the kind of tools employed, and the general mode of procedure. This explanation will enable us better to understand what meets the observation when down in the pits.

The alum-ore is drawn up to the surface near the buildings where the subsequent processes are conducted; but the men descend to the mine at the distance of half a mile from that spot, the same shaft serving for the various classes of miners. This shaft is in the middle of a field, and presents to view nothing more than a square opening measuring about six feet each way, guarded by slight wooden palings at the margin, and having ladders of very small steps for the descent. The depth is not very great—insignificant, indeed, when compared with that of the mines whence metallic ores are procured; and hence the descent has nothing about it very fatiguing. But once arrived at the bottom, we are just as much excluded from the light of day and are exposed to the same rough usage as if we were ten times as far beneath the surface. An old coat and cap, a thick pair of boots, a little lamp, and a little courage, must prepare us for our groping excursion; and we soon find that not one of these can well be spared.

When we follow our guide from the bottom of the descent into the passages of the mine, the profound darkness has at first a very bewildering effect; for the earthy lining of the passages is so nearly black that it reflects very little of the light from the small lamps carried in the hand, and thus the lamps seem like so many specks of light set in—nothing. Under-foot the soil is rather wet and sloppy, and over-head the roof is so low, that a stooping posture is unavoidable. By degrees the eye becomes accustomed to the peculiar gloom of the place; the lamps, which at first only rendered the "darkness visible," now throw a faint glimmer upon a few prominent points, from which we find that we are walking through a low arched passage.

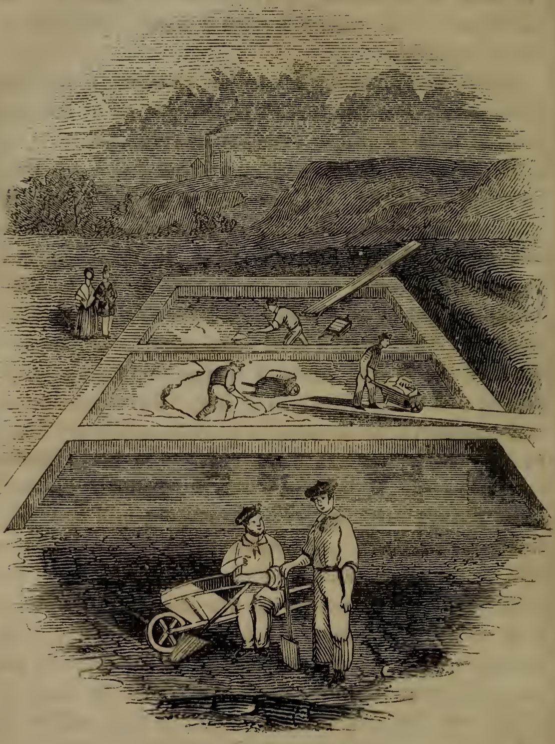
On the occasion when the writer groped through this mine, he accompanied two of the managers, one of whom had cognizance of and superintendence over the operations for the collection of alum, while the other superintended the coal and lime miners; and an opportunity was thus afforded of seeing most of the operations going on. After having walked "in single file" for some considerable distance, we came to the spot where a number of glimmering lights showed that mining operations were being carried on. Some men were seated about on heaps of coal, nearly shrouded in darkness; while others, with bits of lighted candle stuck in their caps, were digging and shovelling coal. One man was preparing a blast; that is, he was placing gunpowder in a cleft of solid coal-rock as a means of riving it. When his operations were completed, all the men retired to a respectful distance, there to remain till the explosion was over; and this interval of a few minutes, though mere matter of course to the miners themselves, is suggestive of some awkward thoughts to those who are new to the subject; for an indefinite expectation of some mischief, which we can neither measure nor guard against, is very apt to arise. However, in the course of a few minutes the fuse was kindled, and the gunpowder exploded; and it was then to be seen that a large mass of coal had been loosened from its bed, upon which the miners immediately set to work.

Having left this spot, we continued our groping through a long series of arched passages; some wet underneath, some dry; some having a railway on the floor for drawing up the "corves" or baskets of coal from a lower level: some high enough to permit walking in an erect posture, others (and these the greater part) so low as to render a painful stooping posture indispensable; some several feet wide, others wide enough only for one person to pass at a time. These passages branched out from one another at all angles and in all directions, till no one but a practised person could form the least conception of the course we were taking, whether away from or round again towards the entrance. For the most part these passages were deserted coal-strata; all the coal having, in the course of years, been removed, except certain portions which were left as pillars to support the roof; and as the stratum of coal thus removed declined at a certain angle in one direction, the void passage acquired the same slope, and thus the transit through the mine is an incline, upward or downward according to the direction.

At one part of the mine we came to a spot where a party of lime-miners were at work. The lime was in the form of very hard stone, and the removal of it was severe labour. The number of lights being considerable, and the white stone affording a good reflecting surface, this part of the mine was more visible than any other. The men had the upper part of the body naked, with the exception of the cap which held the bit of lighted candle: and some, in the intervals of work, were seated on low heaps of stone or rubbish, smoking their short pipes. As to their conversation, it was very little more to be understood by a stranger than Gaelic would have been; for the miners' language is full of words not in use elsewhere, or else differently applied. For instance, in the lead-mines of Derbyshire, a "coffin" is an old working open to the day; a "country" is a rock through which a vein traverses; and "trade" is rubbish or refuse from a mine: again, in Cornwall a "trouble" is a break in the continuity of a vein; an "old man" is a place worked in former ages; and so forth—many of the terms and phrases being common to all miners, while others are peculiar to certain localities. Another group of miners, warming some oatmeal "parritch" over a small fire, and enveloped in the smoke, formed a curious patch in the dusky landscape.

While walking along the arched passages, if the hand were passed over the surface of the roof, or if the head —from want of proper humility—struck against it, we could easily see that the roof was coated with a crumbling powdery substance, easily scraped from the solid rock. This was a decomposed state of the mineral which was afterwards to yield not only alum, but also copperas; the air and damp of the mines having in the course of years brought to an efflorescent state that which would otherwise have been a hard stony substance. In other parts of the vaulted passages specimens might occasionally be picked up, in which a hard slaty substance was interstratified with layers of a greenish-white crystalline body; while in others again a brownish-black kind of coaly-slate was the form in which the alum-ore presented itself, always occurring *above* where the coal had been, and never below it. At another place, being the lowest part of the mine, an area of several acres of water had collected, entirely occupying the deserted workings at that part. This water, when tasted, was found to be strongly impregnated with the two salts—copperas and alum—resulting from the decomposition of the alum-ore which had dropped into the water, or over which the water had trickled.

After groping in this way for three hours, to a distance of four or five miles through the apparently interminable passages of the mine—some of which belonged to one proprietor, some to another, but all leased (in respect to the alum) to one party—we returned to the



[Alum Steeping-pits.]

entrance; not unwilling to exchange a stooping attitude and a dim glimmer for free movement and the light of day.

Let us next see the processes to which the alum-ore is

[Alum Evaporating-boiler.]

subjected. In these mines there was originally a stratum of coal, with a stratum of lime above it, and between the two a thin stratum (varying from two to twelve inches in thickness) of ore containing most of the chemical elements for alum. So long as the coal was not worked, the alum probably remained undisturbed, or at least unworked; but when the whole stratum of coal was removed, the slaty stratum above it was laid bare. In this slaty stratum there are, among other elements, sulphur, alumina, and iron; and these, by the long-continued action of air and moisture, lead to the formation of sulphate of alumina and sulphate of iron. But heat will also lead to this transformation; and thus the operations of the alum-works involve two varieties, one for the efflorescent ore, and the other for the stony ore.

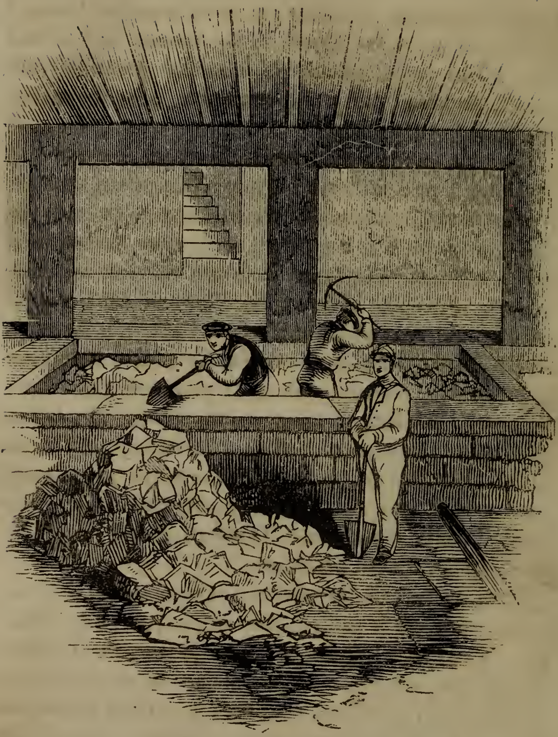
Supposing the crumbled ore (which has a greyish colour and a salt taste) to be scraped and collected from the pit, it is put into large open depositories called *steeps*, freely exposed to the air. It is there covered with water partially impregnated with sulphate of iron and alumina, and allowed to remain undisturbed for several hours, during which time the sulphates become dissolved in the water, and the earthy residue subsides. The water, having imbibed the saline matter from the ore, is drawn off to a settling cistern, and the half-spent ore is steeped again and again with fresh water, until all the soluble matter is completely exhausted.

In the cistern the earthy sediment wholly separates, and from thence the liquor is pumped into a series of long arched boilers, so formed as to apply heat to the surface of the liquid. By this means a considerable portion of the water is evaporated, and the highly concentrated liquor is then transferred to large coolers, where it remains about a fortnight undisturbed. During this interval a process of crystallization goes on: the liquor contains sulphate of iron (copperas) and sulphate of alumina, and the former of these separates from the latter by gradually crystallizing. Sticks called 'riders' are immersed in the liquid in the coolers, and around these sticks large bundles of beautiful green crystals collect, forming the well-known but absurdly-named 'copperas' of the shops.

When the crystals of copperas have been removed, the remaining liquor is drawn off into an evaporating boiler, in order that the sulphate of alumina may go through the same process as the copperas; and, after boiling to a certain strength, the liquor is drawn off into a cooler. Sulphate of alumina will not crystallize without the addition of potash or some other alkali, and potash is therefore put into the cooler with the liquid, by which, after some days' standing, crystals of alum are produced, those crystals being a sulphate of alumina and potash. After this follow other processes of boiling, evaporating, and crystallizing, for the purpose of purifying the alum—processes which give rise to the distinctions of 'green alum,' 'white alum,' and 'finished alum;' but into these details we need not enter.

When, instead of the efflorescent or powdery ore, the hard or stony ore is used, a preparatory process is necessary. This ore (which in appearance is somewhat midway between slate and stone-coal) contains sulphur, iron, and alumina, like the decomposed ore; but these three elements have not yet been combined into the sulphates of iron and of alumina; and the aid of fire is necessary for this transformation. The ore, after being broken into small pieces, is built up into long ridges, with fuel beneath and air-holes in different parts; and here it is burned as a preparative process.

It will thus be seen that the copperas is an extra prize



[Alum Crystallizing Coolers.]

which the alum-maker obtains from the ore, when the latter has been decomposed by the air; and that the four main processes, varied somewhat in detail, are roasting, steeping, boiling, and crystallizing; and the alum thus made is forthwith ready for use in dyeing, in tanning, and numerous other branches of manufacture.

This, then, is the process for obtaining alum from the crude ore; but we must now notice the mode of preparing it from the elements themselves, as practised at some of the large chemical works. As we before observed, crystallized alum is called chemically a "sulphate of alumina and potash;" being composed of sulphuric acid, alumina or pure clay, and potash; and provided those three agents can be properly brought together in proper proportions, they will still form alum, whether derived from decomposed ore or from the mixture of the different agents.

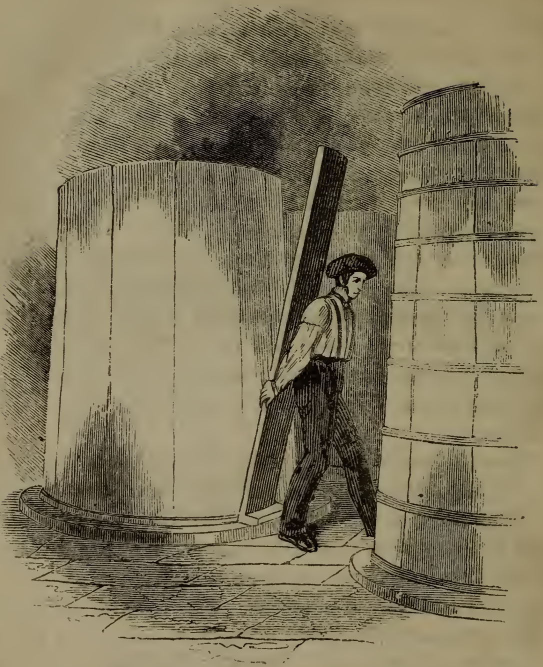
The buildings appropriated to the alum manufacture have their own vessels and their own peculiar arrangements, some of them very interesting. The alumina is procured from Cornish clay, a fine, smooth, and white clay, which is extensively employed in the manufacture of porcelain and the finer kinds of pottery. This clay is brought from Cornwall in balls or blocks, as dug out of the earth, and is ground under a heavy stone to a state of great fineness. The powdered clay is calcined in an appropriate oven, to drive off the moisture and vegetable matter which may be combined with it. The calcined clay is next placed in an oval tank sunk in the ground; and to this is added the second ingredient necessary to form alum—that is, sulphuric acid. The acid has such a powerful action on the clay, that the two together soon form a boiling mixture, although no heat whatever is applied to it; the instance being one of those in which rapid chemical combination gives rise to the evolution of heat.

When these two agents have combined, they are mixed with a considerable quantity of water, and allowed to settle, by which those solid parts of the clay which resist the action of the acid are allowed to fall to the bottom of the vessel. The liquid (which is a solution of sulphate of alumina) is then pumped up into leaden vessels, where it receives the addition of some sulphate of potash, as a means of giving the third ingredient necessary to the formation of crystallized alum. The different ingredients are allowed to remain quiet in a circular sunk vessel, where the alum gradually crystallizes round the sides, shooting forth large crystals towards the centre, where the mother-liquor (or portion which will not crystallize) remains.

But the alum thus produced is not pure and fine in quality. It undergoes the process of *roaching*, to bring it to a better condition. This roaching (or roching, as it may perhaps more properly be spelled) is probably meant to imply the production of an alum similar to roch alum; and this latter derived its name from Roccha in Syria, where it was first made. In the process of roching, steam is allowed to act upon the alum, so as to dissolve it, and to make with it a very strong solution. This is done in a leaden vessel; and from this vessel the solution is transferred to large cylindrical crystallizing vessels, where it attains the final state in which it is sent to market.

When the crystallization is complete, the cylindrical vessels present a very beautiful exemplification of this kind of chemical action. They are about seven feet high by five in diameter; and upon looking in at the top of any one of them, we see a thick hollow cylinder of crystallized alum, with a portion of floating water in the centre: the mass appears like an irregular rock-work of sparkling transparent crystals, many of them of large dimensions, and all with the most perfect symmetry of form, presenting the keen apex, the fine, clear, straight edges, and the regular and even faces of the 'octohedron,' the geometrical form which these crystals assume. The manner, too, in which the alum is extracted from the vessels is calculated to show the beauty of the crystallization. The vessels are capable of being taken to pieces as they stand, by the removal of certain hoops and staves; and the alum is then exhibited to the eye as if it were one magnificent cylindrical crystal, as large as the interior of the vessel had been. The liquor is removed from the inside, and the alum, being broken up into convenient fragments, is packed in barrels for the market.

There is one peculiarity about alum which has led to an entirely new branch of manufacture, now being carried on extensively at one of the large works. We have said that it is a sulphate of alumina and potash. But it is not necessarily so: in some instances soda, in others ammonia, has been used instead of potash. The truth is, that these ingredients are used chiefly as agents to induce the crystallization of the alum. Sulphate of alumina will not crystallize; the sulphuric acid and the alumina have combined, and the resulting compound possesses most of the useful properties of alum; but it cannot, by itself, be brought into a crystalline form. When, however, any one of the three above-mentioned alkalis is added, the sulphate acquires this power, and becomes a crystallized sulphate of alumina and alkali. On the other hand, this alkali is of no practical service in the chief purposes to



[Cylindrical Mass of Crystallized Alum.]

which alum is applied in the arts: the sulphate of alumina is the real working agent; and if this could be obtained in a pure state and in a solid form, the alkali would in most cases be unnecessary. It happens that the iron contained in small quantity in the clay, and which would injure the alum if allowed to form one of its constituents, is with difficulty removed except by some mode of crystallizing the alum; and it is not until recently that the difficulty has been practically removed, by the production of a "patent alum," the chief characteristic of which is that it possesses the efficient properties of alum, but without containing potash. In making this alum, sulphuric acid and Cornish clay are used, as in the other case; but the clay is used in greater proportion, so as to form a kind of mortar or thick paste. This mortar is placed in a heated trough, where the moisture is so far evaporated as to convert the mass to the form of a dry earth. From the trough it is removed to tanks, where water is employed to dissolve it; and while in the liquid state the composition is acted upon by an agent intended to remove the iron: this being the only contained ingredient which is injurious to the alum. The agent employed attracts or combines with the iron existing in the clay, forming with it the coloured pigment known as Prussian blue. This Prussian blue is allowed to subside, and the remaining liquor, being a solution of sulphate of alumina, is boiled till all the water is driven off. The solid residue is formed into cakes an inch or two in thickness, and in this form it comes into the market. Instead of being a crystal, it is an opaque earthy solid, differing from common alum in the circumstance of containing no potash, but possessing in common with it the qualities which render it valuable in the arts.

The Prussian blue is procured in far too large quantity to be allowed to remain in that state: it is restored again, by chemical means, to the form which it before presented, ready to be again used in making more alum. This principle is exhibited in many departments of a chemical work: where a chemical substance, after being modified in its character by the aid it has afforded in making other substances, is restored to its original form, and thereby fitted to render similar aid in other instances.

In many of the works where these complicated processes are being carried on, the mechanical arrangements are on a very large scale. In one that we have seen, there are five steam-engines in different parts of the works, for pumping up water, pumping liquids from one vessel to another, setting in motion the mills and stones for grinding clay and lime, and other operations requiring great motive power. There are carpenters' shops, smiths' shops, coopers' shops, plumbers' shops, and others of a similar kind for keeping in working order the various vessels employed in the works; the lead vessels and pipes, especially, are so numerous, that there is constant work for plumbers in one way or other. There is also an important department which we may perhaps term the very grammar of the whole, viz. the *laboratory*, the spot wherein are determined the numerous points connected with the chemical science of the manufactures. This laboratory contains all the appliances for such a purpose —air-furnaces, reverberatory furnaces, sand-baths, stills, retorts, and the varied apparatus for experimental trials on the mutual action of chemical agents. A chemical library, too, is a necessary appendage to such a place.

When, leaving the actual buildings themselves, we go out upon the spoil-bank or mound of rubbish, we there get a bird's-eye view of the arrangements whereby the works are connected with the means of transit. Railways traverse the ground in all directions, affording easy means of communication. In the first place the coarse materials, such as sulphur, salt, lime, coal, &c., are landed at a wharf; and are thence hauled up an inclined railway, through a tunnel, to the works, by means of steam-power; and when arrived there, other railways convey these materials to the various buildings wherein they are to be brought to bear upon the manufactures. Then, when the manufactured goods are finished, the same system of railways furnishes a medium for conveying them down to a busy river, there to be shipped off to various quarters.

Such are chemical works. Some manufacturers make one kind of acid or of alkali, some another; one firm may have a reputation for a particular kind of salt or chemical agent, another for another; and, to understand the minute details, it would be necessary to follow the manufacturing routine of all the substances one by one. But the broad principles are the same in all. There is in all of these works the same exhibition of lofty chimneys, large and variously arranged buildings, furnaces, and ovens in almost endless variety, boilers, heaters, coolers, stills, crystallizing vessels, cisterns, tanks, pans, and a multiplicity of other apparatus; while they all likewise agree more or less in this—that there is no lack of odours from some of the chemicals under process of manufacture. It is perhaps scarcely necessary to remark, that the shops of the chemists and druggists are supplied with drugs of these various kinds from the chemical works, through the agency of wholesale dealers. There are in London several wholesale druggists who accumulate in their warehouses the crude drugs from every part of the world, not only from the chemical manufacturers, but from foreign merchants and dealers; and these drugs, passing into the hands of the retailers, are by them sold in smaller quantities, or are made up into the various well-known pharmaceutical preparations.

CHAPTER IV.

ON THE SOAP, POTASH, AND CANDLE MANUFACTURES.

In the preceding chapter several chemical products were described which seem, at first glance, to have no particular connexion one with another; but when we look at the mode of production, we see that from sulphur and common salt, as two of the principal agents, are produced sulphuric acid, chlorine, bleaching-powder, soda and carbonate of soda in various forms, and alum—substances having a widely diverse character; and if we were to extend our research further, we should find that a large number of other bodies are produced, more or less directly, from the same agency. If this little volume pretended to a completeness of system, all these matters should be noticed one by one; but it is only on the plan of presenting a few, as an index and a general exemplification of many, that we could at all accomplish what is aimed at in this place.

Let us next, then, select a kind of manufacture in which alkalis and acids and salts are not so much the object of the manufacture, as the means of producing something else. *Soap* will be a convenient example of this class; and as *candles* are very frequently made in the same factories as soap, a little notice of those likewise may be desirable.

In one such factory, situated in a busy part of London, the following are the general arrangements; and these may be taken as a type of many others. An outer gateway gives admittance to an open court, surrounded by various houses, buildings, and offices. In the open court are waggons and carts, laden either with the raw materials from whence soap and candles are to be made, or with the manufactured articles about to leave the premises. Of the offices and counting-house we need say nothing; they contain the usual arrangements for the partners and clerks in the establishment. Contiguous to these offices is a small laboratory fitted up with a furnace, a sand-bath, a distilling apparatus, and other conveniences for conducting the chemical analysis of soap, and for making experiments incidental to the manufacture. The manufacture of soap is conducted in the warehouses westward and northward of the offices; while the candle department lies eastward.

The building in which the main operations of the soap-manufacture are carried on covers a large area of ground, and is nearly filled with coppers and vessels of considerable dimensions. It is technically known in the factory as the 'Copper-side;' but we shall perhaps be better understood if we term it the 'boiling-house.' As we pass along the central avenue of this building from south to north, we have on the right hand a range of coppers or boilers, nearly a dozen in number, and averaging about eight or ten feet in diameter, the height being between four and five. These coppers are filled with soap or the materials for its formation, in various stages of progress. In one the soap is nearly in a finished state, and is about to be removed; in another the ingredients are boiling, and sending up a profuse volume of steam; into a third a supply of alkaline liquor is being conducted from vats wherein it is prepared; from a fourth the spent ley or liquor is being pumped, after having imparted its alkaline property to the soap; some are for 'mottled' soap, some for 'yellow,' some for 'white' or 'curd' soap. According to the time when the 'boiling-house' is visited, so will these operations vary; but in general the contents of the coppers show the soap in many different degrees of formation. These coppers, as in many other instances, are oddly termed, for they are in reality iron vessels surrounded with brick. No flues or fires of any kind are connected with them; the boilers are heated by steam constantly passing from a large boiler which supplies all these vessels, and which is situated in another part of the factory. The introduction of the method of heating by steam instead of fire, in soap-factories, sugar-refineries, and other establishments, is one of the most important improvements of modern times; economizing space and fuel, maintaining an equable temperature, and lessening the liability to accidents by fire. In each copper is a pump, for removing the spent ley at a particular period in the process.

Along the left hand of the avenue, through the boiling-house and opposite tne boilers, is a row of alkali vats, in which the alkali is brought into a purified and liquid state. The alkali employed in soap-making, and which is a crude carbonate of soda or of potash, is brought to the factory in a dry greyish powder; but before it can be used in the manufacture, the carbonic acid must be removed from the alkali, leaving the latter in a caustic state. This we shall explain further on; but we here merely observe that the vats in which this purification takes place are situated a few feet to the left of the boiling-coppers, and that a shoot or trough conducts the liquid alkali from the vats to the coppers.

Adjoining the boiling-house on the left is a passage leading down to a wharf, through which is conveyed the carbonate of lime resulting from the purification of the alkalis, a residuum which is extensively used as a manure on stiff lands: its beneficial effect is much increased by the small quantity of alkali and salt which it contains. Very interesting accounts have been published at various times exhibiting the effect of this manure on particular plants; and indeed a considerable quantity has been shipped to the West Indies since the abolition of slavery. On the right of the boiling-house, and communicating with it by a door, is the 'frame-room,' to which the soap is conveyed after being made; the name of *frame* being given to the vessel or receptacle into which the made soap is poured, and in which it remains till cold. The frame-room is full of these receptacles, nearly a hundred and fifty in number, lying in ranks or rows side by side, and the rows opposite each other. In walking between these rows of frames we see in one place a man filling a frame with liquid soap; in another, men taking a frame to pieces after the solidifying of the soap; in a third, other men cutting up a mass of hardened soap into slabs.

Near the frame-room is a range of warerooms, in which the slabs of soap are cut up into bars, and then piled up in tiers, like bricks in a wall. If "cleanliness is next to godliness," according to the adage, we ought to have very pleasant thoughts while passing between these walls of soap—here 'mottled'—there 'yellow'—in another part 'curd,' and so on; but the truth is, that the odour from such a mass of soap, and the unavoidable absence of cleanliness in the manufacture, somewhat disturb the pleasure of contemplating the ulterior purpose to which the soap is to be applied.

In other parts of the factory, according to convenience, are placed the boiling-house for soft soap, and warehouses connected with it. The soft-soap copper is heated and managed in the same manner as the coppers for the hard soaps, and holds fourteen or fifteen thousand pounds of soap. As this kind of soap is not of such consistence as to enable it to be cut into slabs or bars, it is packed in barrels and sent from the factory in a pasty or semi-fluid state. In connection with this part of the factory, too, are six or eight vats for de-carbonizing and purifying the carbonate of potash used as the alkali for soft soap. Besides these buildings and rooms, there is in one part of the soap department a storeroom or warehouse for tallow; in another, a similar depository for alkalis; in a third, for resin (an important ingredient in yellow soap); in a fourth, for oil; in another for 'kitchen-stuff,' an ingredient in the commoner kinds of soap. There is one room in which barrels of palm-oil are kept, and in which the oil—solid in our climate—is melted out of the cask through the bung-hole by means of steam. In another spot the oil thus melted is purified and bleached, and brought into a state fit for the soap-manufacture. Other rooms, or portions of rooms, are devoted to various subsidiary processes relating to the soap-manufacture; but to which we need not pay particular notice.

After having thus glanced generally at the various portions of the soap department, we may next briefly notice the arrangement of the candle department, which, although much less considerable in size, presents many ingenious arrangements, and many curious applications of the division of labour. The principal room in this department is that in which the 'dip' or 'store' candles are made, and which we may perhaps term the 'dipping-room.' This is, to the eye of a stranger, the most singular-looking room in the factory. It is of considerable height, having two stories or floors, one extending over the bottom in the usual way, and the other forming a kind of gallery round the four sides, at the height of about twelve feet from the floor. An inclined plane leads down from the gallery at one end to the floor at the other, consisting of a platform with ledges of wood at distances of about a foot asunder, forming a kind of an apology for a flight of stairs: it is, indeed, a kind of staircase, such as is used by ship-builders to ascend the sides of a ship, and is adapted by the smallness of its angle of elevation for the ascent of persons carrying loads. The floor or ground of the room is devoted to the manufacture of the candles, and the gallery to some subsequent operations. Along the middle of the floor is a row of cisterns, filled with tallow in a hot and melted state, which is kept at a proper temperature. Around the room on all four sides, and distant a few feet from the cisterns, are reservoirs or vessels of melted tallow, filled from the central cisterns, and consumed in the process of making candles. Between and above are candles, or the skeletons of candles, hanging in thousands; some having had only a single garment of tallow to cover the nakedness of the wicks; some more plentifully coated; and some nearly in a finished state. On three sides of the room men are making candles by the aid of the machines which we shall speak of by and by; while in other parts of the room other men are 'dipping' according to the method in use before the invention of the machines. Here, a man is replenishing the supply of hot tallow in his dipping-cistern, from the cisterns in the middle of the room; there, is a boy removing the made candles from the machines, and fitting on a new supply of wicks; while other men and boys are busied in various parts of the manufacture.

On ascending the inclined plane to the gallery, we see near the outer edge of the gallery candles hanging on sticks; and round the gallery, next the wall, are a series of work-benches or tables, at each of which a man and a boy are engaged, the one to weigh the candles, according as they are 'eights,' 'tens,' 'twelves,' &c., denominations too well known to every housewife to need explanation; and the other to fasten the candles on a string. In a small room attached to the candle department is kept the store of rushes for making rushlights; they are gathered in Lancashire, and brought to town in bundles weighing a few pounds each. In another room are sacks or bags filled with cotton, wound up in balls of about three pounds weight. There is also a beautiful machine, at which a man is engaged in making wicks for 'mould' and 'dip' candles. A third room, larger than those just alluded to, is the 'mould-room,' in which the mould candles are made, by the aid of an elaborate and ingenious machine. Connected with the candle department, also, are the requisite stores and warerooms for the commercial arrangements of the establishment.

Besides the various buildings and rooms belonging particularly to the soap or candle departments of the factory, there are mechanical and other arrangements of a general kind, which need not much description. In convenient parts of the factory are two steam-engines of different horse-power. Near these is a blacksmith's shop, for the repair and adjustment of various kinds of iron-work used in the factory. The smoke from the different flues and furnaces is conducted into a chimney of large dimensions. A carpenter's shop furnishes the conveniences for making packing-cases, boxes, &c., for the commercial department. Lastly, and perhaps to the manufacturers the least pleasant of all, there are rooms and offices fitted up for the Excise-officers, one or more of whom are in the factory day and night. It is a great blot upon the fiscal arrangements of this country, and one which seriously affects the manufacture of malt, of glass, of soap, and many other articles, that in order to collect the duties levied on these commodities, the officers of the Excise are empowered to control, as it were, every step of the processes, and to regulate the extent to which any improvement in the operations may be carried. It is not the amount of duty collected to which we here refer; this is another subject: it is the mode of collection which is so objectionable, by imposing impolitic checks to the natural course of improvement in manufacturing processes. Considerable ameliorations have, however, within a recent period, been made in the mode of collecting the revenue, and the survey of the premises of soap-manufacturers.

There is a curious account of this trade in a small pamphlet, printed for Nicholas Bourne, in 1641, entitled 'A Short and True Narrative concerning the Soap Business.' It contains an account of a patent granted to a Company for the exclusive manufacture of soap, under the title of the 'Governor, Assistants, and Fellows of the Society of Soapmakers of Westminster' (1622), on condition of their paying to his majesty 4*l.* per ton on 5000 tons annually. The manufacturers of that day (twenty in number) refused to join and acknowledge this Company; whereupon the Company obtained a proclamation forbidding, amongst other things, the sale of soap which had not been assayed by the Company. An information was then exhibited in the Star Chamber (1633) against sixteen London makers for opposing and affronting the letters-patent; to which the defendants pleaded and demurred, &c., and after much discussion (all the defendants having been committed to prison for having put in their answer one day too late) the judges certified "all the answer except the first four words and last ten as fit to be expunged;" and it was decreed that the defendants be imprisoned during his majesty's pleasure, and fined in various sums from 1500*l.* to 500*l.* All were sent to prison. Fourteen remained there for forty weeks, and two died in prison. These tyrannical acts were followed by various proclamations and orders in council restricting the manufacture of soap except by the patentees, and fixing the price at which soap should be sold, and the materials from which it should be made. In 1635 many other soapmakers were committed to prison, and greater power was given by proclamation to the patentees upon their covenanting to pay 6*l.* per ton on 5000 tons annually. In a short time, however, the patentees, having "vexed the whole kingdom with their soap for three years," obtained a warrant from his majesty (1637) for 40,000*l.* for giving up the patent, and 3000*l.* for their houses, and obliged the soapmakers of London to pay them 20,000*l.*

for their materials, so that they might have use of their trade again, of which they had been deprived. Little is known of the trade from this time to 1704, when Queen Anne imposed the first Excise duty. Several pamphlets and statements, on half-sheets, are to be found in the British Museum, containing petitions to be relieved from taxes, &c., but there is no account of the quantity manufactured.

We shall now give a description of the processes whereby certain raw materials are converted into the well-known forms of soap and candles. Strictly speaking, there is a great deal of chemical nicety involved in the manufacture, both in theory and practice ; but this is not the place where such matters can be consistently treated in a scientific manner. A rapid sketch of the nature and sources of the materials employed, and of their gradual transformation into the manufactured articles, will fill up the measure of our object.

Soap is designated in the 'Penny Cyclopædia' as a compound derived from the union between fat or oily substances and alkalis ; and the nature of its formation is expressed in the following terms :—" It has been found by Chevreul that different varieties of fatty matter consist chiefly of two parts : one hard, to which he gave the name of stearin ; and the other soft, which he termed olein. He also discovered that stearin is composed of stearic acid, and a peculiar principle, which, on account of its sweet taste, he named glycerin. When, in the manufacture of soap, an alkali (soda, for example) is heated with tallow, the soda gradually dislodges the glycerin from combination with the stearic and oleic acids, and by combining with them forms soap, or, in other words, a compound of stearate and oleate of soda, and the glycerin remains in solution." That the manufacture of this substance from the two classes of ingredients here mentioned has been long known is sufficiently indicated by a circumstance mentioned by Mr. Parkes in his 'Chemical Essays:'—"On examining the excavations that were made on the spot where this famous city (Pompeii) formerly stood, a complete soapboiler's shop was discovered, with soap in it, which had evidently been made by the combination of oil and an alkali. This soap was still perfect, though it had been manufactured more than seventeen hundred years."

As there are many kinds of fat and oil, and two very distinct kinds of alkali employed, it naturally follows that the soap will possess different qualities, and present different appearances, according to the ingredients.

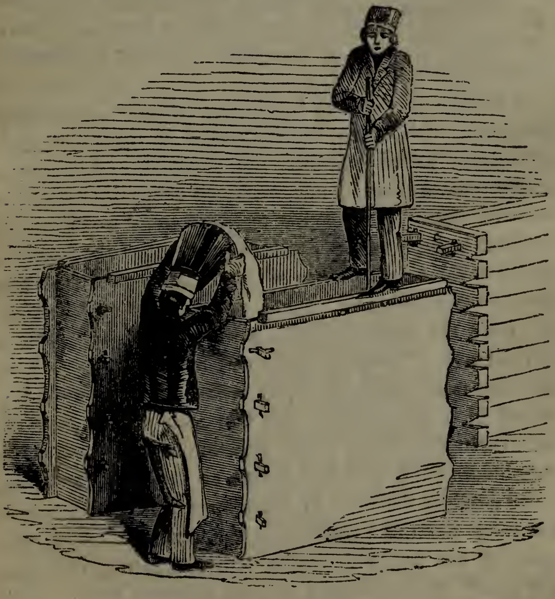
Mottled soap is made from tallow, soda, a little 'kitchen-stuff,' a minute quantity of salt, and water. Its analysis is—alkali, 6·5; grease, 62·5; water, 31·0: total, 100. The tallow principally employed in the soap-factories of England is brought from Russia, forming five-sevenths of the quantity exported from the last-named country. It is exported in a solid state in barrels. So large a quantity of this substance is used in England, that about thirteen hundred thousand cwts. are imported every year, yielding to the revenue somewhere about two hundred thousand pounds sterling. The tallow arrives in this country in a tolerably pure state, and requires no preparation previous to its employment in making soap. The heterogeneous substance known to domestic servants and 'dealers in marine-stores' by the name of kitchen-stuff, although very impure, is capable of being cleansed and refined, and used in the same manner and for the same purposes as tallow: it is heated in a copper, strained, and otherwise freed from the extraneous substances which are mingled with the tallow. It is only in the coarser kinds of soap that this material is used.

The alkali used for mottled soap is soda, the gradual changes in the production of which form a curious episode in the history of the soap-manufacture. Although the form in which the alkali is used by the manufacturer is that of caustic soda, almost or entirely free from any acids, yet the state in which it is sold is that of a carbonate, more or less mingled with impurities. The barilla and kelp were until lately the only sources from which this alkali was derived; the one of foreign production, and the other British. Barilla is a kind of ash obtained by burning a South-European plant called the Salsola soda, which plant is cultivated with great care by the Spaniards and the Italians. A few years since there were 6000 tons imported annually from Spain, Sicily, and Sardinia; and formerly the quantity was much greater.

Kelp, another form of the carbonate of soda, alluded to above, is the ash remaining after the burning of sea-weed. It contains only a little of the alkaline salt, but a large quantity of common salt, some salts of potash, and other substances. Previous to the year 1822, a duty of eleven or twelve shillings per cwt. being laid on barilla, a considerable quantity of kelp was made on the coasts of Ireland; and about a century ago from the present time the manufacture was begun in Scotland, where, in consequence, the land in certain localities by the sea-shore became greatly advanced in value, very large annual revenues being derived from estates which had previously been wholly unproductive. Dr. M'Culloch gives a graphic account of the kelp manufacture in its most flourishing state :—" The kelp season had now commenced, and the whole shore was one continued line of fires ; the grey smoke streaming away from each on the surface of the water, till, mixing with the breeze, it diffused its odoriferous haze over all the surrounding atmosphere. . . . . The weeds, being cut by the sickle at low-water, are brought on shore by a very simple and ingenious process. A rope of heath or birch is laid beyond them, and the ends being carried up beyond the high-water mark, the whole floats as the tide rises, and thus, by shortening the ropes, is compelled to settle above the wash of the sea, whence it is conveyed to dry land on horseback. The more quickly it is dried the better the produce ; and when dry it is burned in coffers, generally constructed with stone, sometimes merely excavated in the earth. In Orkney the latter are preferred. As twenty-four tons of weed at a medium are required to form a ton of kelp, it is easy to conceive the labour employed for this quantity in the several processes of cutting, landing, carrying, drying, stacking, and burning."

How strangely do variations in one branch of commerce affect the arrangements of another! Twenty years ago common table-salt was sold at four or five pence per pound ; but when the duty was wholly removed, this price fell to one halfpenny. Manufacturers immediately turned their attention to this substance, as a source whence saleable commodities might be produced. Common salt is formed (as explained in the last chapter) of chlorine and sodium ; and by chemical agency the two can be separated, and each one made to combine with some other substance. Such has been the case in respect to the soda used in the soap-manufacture: by far the greater part of it is produced from the sodium which forms one of the ingredients in common salt, the decomposition of which in sufficient quantities to supply the soap and glass makers has for some years employed large capitals and many hundreds of workmen. This alkali, or 'white ash,' as it is called, made from salt, has driven kelp and barilla out of use. The rough carbonate of soda, as brought from the chemical-works to the soap-works, is subjected to a process whereby the carbonic acid is driven from the carbonate, leaving the soda in a caustic state, and forming, when in solution with water, the liquor which soapmakers call a ley or lye. The ley is pumped out of the vats into the boilers, where it is mixed with the requisite quantity of tallow, and any other fatty substance which may be employed. The mixture is then heated by steam, and well boiled, an attendant stirring the mass occasionally. After a time the tallow is found to have combined with a portion of the ley, including all the alkali, and the remaining, or spent ley, is then of no further use in the process. It is pumped up from beneath the soap by a pump whose barrel descends to the bottom of the copper; and a fresh supply of ley is introduced. Again and again is this process repeated, new leys being introduced after the spent liquor is withdrawn, and the leys being used in a stronger or more alkaline state as the process advances towards completion. When the soap is nearly finished, that peculiar appearance to which it owes the name of 'mottled' soap is given to it by sprinkling upon the surface a small quantity of very dense and strong ley; this percolates slowly through the mass of soap, and leaves in its track those dark-coloured veins which constitute mottling.

When the tallow and alkali have completely formed into soap, and have attained a proper consistency, the soap is laded from the coppers in buckets or pails, and conveyed to the frame-room, where it is poured into the frames. These frames have, until within the last few years, been made wholly of wood, but cast-iron frames



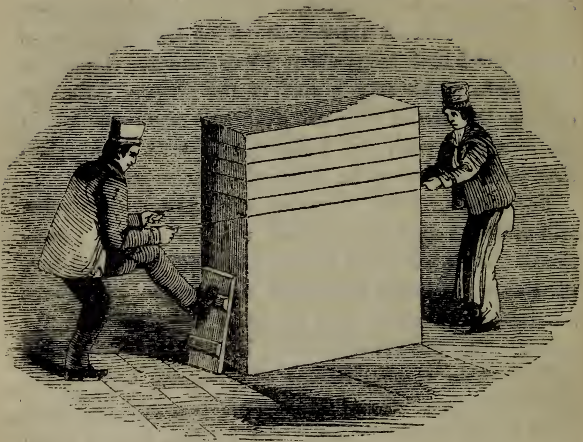
[Filling Soap-frames.]

are now occasionally used. The wooden frame is a kind of well or cistern, formed of a pile or heap of frames laid one on another. Each separate part consists of a rectangle of four bars of wood, measuring internally forty-five inches by fifteen; and these rectangles are laid one upon another to a height of ten or twelve feet. The bars of the rectangles are so neatly squared and smoothed as to fit closely one upon another. The mottled soap is poured into these frames until full, and there allowed to remain till cold, which occupies more or less time according to the state of the weather.

When the mass of soap is cold and solidified, some iron fastenings, with which the rectangles of the frame had been firmly bound together, are loosened, and the rectangles removed one by one, each one being lifted off the mass of soap. The soap is then presented to view as a compact body, whose dimensions are those of the interior cavity of the frame. Some of these masses of soap weigh three or four thousand pounds each. The next process is to cut the mass into slabs or slices about three inches in thickness. To effect this a man marks the surface of the soap with parallel lines, by means of sharp points inserted in a gauge-stick; and two men draw a piece of wire through the soap in the direction of each mark, one man holding the wire by handles at the ends, and the other guiding the wire to the proper marks. The slabs are next taken to a machine in the form of a hollow box open at the top, with vertical crevices passing from the top nearly to the bottom of two opposite sides. The slabs being ranged horizontally in this box, a piece of wire is passed down each of the crevices in succession, cutting through the slabs in its progress. As the crevices are about three inches apart, it follows that the slabs are cut into bars about three inches wide and the same in depth, the length being about fifteen inches. These are the bars in which soap is sold in the shops. After the cutting, the bars of soap are piled one upon another in the form of a wall, and kept in that state for a certain time until required to be removed from the factory.

For curd or white soap the same general description will suffice as applies to mottled, with some minor exceptions. As its whiteness is one of its chief characteristics, the tallow is selected with more care, and no ingredients are introduced which will be liable to deteriorate the colour. The process of mottling is in this case dispensed with; but the general outline of processes, such as the de-carbonising of the alkali, the melting and boiling of the ingredients, the framing, the cutting, &c., is much the same as in the manufacture of mottled soap.

Yellow soap is less expensive than white or mottled; and it owes this cheapness, as well as its colour, and certain properties which it possesses, to the large employment of palm-oil and resin in its composition. Although resin is in appearance very different from tallow, yet it possesses the same property of melting and combining with an alkali, and forming a soap by the combination. The analysis differs little in pure soap from that of mottled, and consists generally of 6 alkali, 62 grease, 32 water. Inferior soap, although in appearance nearly the same, contains from 10 to 20 per cent more water, and is proportionally less efficacious—a fact worth the notice of those who are prone to buy "cheap" commodities. The nature and source of resin will be briefly described in another chapter. Palm-oil is obtained from the oil-palm of



[Cutting Soap.]

Guinea, cultivated in the western parts of Africa. The fruit of this tree is ovoid, about the size of a pigeon's egg, with its outer fleshy covering of a golden yellow colour. The oil is obtained by bruising the fleshy part of the fruit, and subjecting the bruised paste to boiling water in wooden mortars: an oil of an orange-yellow colour separates, which concretes, when cool, to the consistence of butter, and has, when fresh, the smell of violets, and a slightly sweetish taste. The Africans use this oil in cookery, and for anointing the body; but when imported into England, it is used in soap-making, in perfumery, and in medicine, for which purposes two or three hundred thousand cwts. are used annually. When brought to the soap-factory it is in casks in a solid state; and the mode adopted for extracting it, is to place the cask over a trough with its bunghole downwards, and to pass a steam-pipe into the cask, by which means the palm-oil is brought to a liquid state and made to flow out of the cask. The oil is afterwards conveyed to a vat, where it is bleached by a chemical process.

The mode of preparing the alkali for yellow soap, the process of melting and boiling it with the tallow and resin, and the general routine of manufacture, differ but little from those relating to mottled soap. The frames used are, however, very different. They are made of five pieces of cast-iron: one for the bottom, two for the sides, and two for the ends. By a simple mode of fastening at the edges, the whole can be quickly put together, so as to form a sort of well or cistern, between four and five feet high, forty-five inches long and fifteen wide. Into these frames the yellow soap is poured, the contents of each being about fifteen cwt. These frames are not only put together and taken to pieces with more ease than the wooden frames, but the iron being a good conductor of heat, the process of cooling is effected more rapidly. The cutting of yellow soap into slabs and bars is effected in the same way as that of mottled.

Soft soap, a commodity which is almost exclusively used in the woollen manufacture, differs considerably from hard soap in its ingredients, its consistence, and its general appearance. Both the alkaline and the oleaginous ingredients are different from those employed in hard soaps; since potash is employed instead of soda, and oils are more largely used than tallow. This soap, when of good quality, consists of alkali, 9; oil and tallow, 42; water, 49: total, 100. The potash employed in the soap-manufacture is brought principally from Canada and the United States.

The carbonate of potash is rendered caustic, that is, free from carbonic acid, by a process similar to that adopted for the soda alkali.

The oils employed in soft soap, whether whale, seal, olive, or linseed, are procured in the usual way, from the blubber of the two former, the fruit of the third, and the seed of the fourth. The mode of combining the ingredients to form this kind of soap does not require any lengthened notice. It may, however, be remarked, that instead of supplying successive portions of alkaline ley to the boiler, and pumping out the spent ley at intervals, the whole of the ley is supplied at once, and kept boiling with the oils and tallow until the soap is made. The use of the tallow employed is to give consistency to the oil soap, the general quality of which is indicated by the gradual formation of white specks throughout the soap, which arise from the combination of the tallow with the salts of potash. Soft soap, as its name imports, has a consistence which renders useless the processes of framing and cutting: it is placed in barrels or casks, when finished, and in that state sent from the factory.

With respect to the large variety of soaps known as 'toilet,' 'fancy,' or 'perfumed' soaps, little need be said here. They are generally made from good white soap, which is remelted and modified in its form and appearance by perfumes and other substances. None of these fancy soaps are made at the large factories; they are either the production of persons who devote their attention principally to the manufacture, or else of perfumers, who apply the fanciful terms—'soap à la rose,' 'soap au bouquet,' 'cinnamon soap,' 'Windsor soap,' 'musk soap,' 'almond soap,' &c., to their manufactures.

POTASH.

Before entering on the subject of the manufacture of candles, it may be well to speak briefly of the source whence our soap-makers and others procure the *potash*, which is now so largely used in manufactures. The following details are from a gentleman who has witnessed the whole operation in America:—

"Many of the enterprising settlers in several of the districts of Upper Canada (the great local divisions of that country being known under the name of Districts) have for many years been engaged in the rude manufacture of an article universally known in that country under the name of 'Black Salts,'—but which, in fact, is the ordinary potash in a crude and very impure state. It is not a little singular that in scarcely another British colony besides Upper Canada, either in North America or elsewhere, or, indeed, nearly throughout the whole territories of the United States, do the settlers devote much of their attention to this subject; although, in very many instances, there is no obstacle to their doing so with as great (and in some cases greater) probability of being amply repaid for their trouble, since many other countries yield nearly or precisely the same species of forest-trees as the black salts of Canada are made from, and they have greater facilities for procuring the necessary pans and vessels to make it in.

"All who have ever entertained any peculiar interest regarding new colonies, and their becoming peopled and the wilderness subdued, will be aware, I presume, that one of the chief and primary obstacles the first settlers have to encounter, is that which the state of the primeval forest presents; for in many of our colonies, and our North American ones particularly, the entire country, when first entered upon by a race of enterprising settlers, is one interminable wilderness of forest-trees. Now, until means be taken either to annihilate those trees by cutting them down and then burning them, or to destroy the vital principle in them, and so leave them standing for a season, by a process called 'girdling'—that is, by cutting a circular notch quite round the tree, and completely through both the outer and inner bark—afterwards leaving them standing until through absolute decay they fall of their own accord,—the land cannot possibly be made to produce any of the necessaries of life, nor sustenance for any description of farm-stock. Among the poorer and more indolent portion of the settlers, in some particular districts, the system of girdling is practised to a considerable extent; but this certainly is a slovenly method of preparing the soil for crops of either grass or grain, and one which never ought to be adopted by such as possess the means of clearing off the timber in a better and more legitimate way, namely, by first cutting down all the trees, great and small, and afterwards having them cut into convenient lengths to be drawn together by oxen or rolled together by the use of handspikes, preparatory to their being set fire to, and burned, root and branch.

"The soil of Upper Canada being, for the most part, of a good quality, many of the trees grow to a large size; and the usual phrase of the country employed to designate the forest with this growth of timber upon it, is, 'heavily timbered land.' We are in the habit of hearing much said about the very low rate at which land of a pretty good quality may be bought in Upper Canada and elsewhere; but in many places where the fee-simple of the soil might be purchased for 10*s*. or 12*s*. sterling the acre, the cost of clearing off the timber will amount to four or five times as much, thus making the first cost fully 3*l*. per acre; and if I were to include the fencing, probably 10*s*. or 15*s*. more. But in several of the most flourishing settlements, from the Head (as it is called) of Lake Ontario, westward the whole length of Lake Erie, many of the more enterprising settlers, as I before remarked, are in the habit of turning the timber to account, in a way that used never to be thought of, or, at all events, never attempted, that is, by the manufacture of crude potash, or 'black salts,' from the ashes of the burned timber; and since the process generally adopted by the Canadian settlers is a very simple one, and one that might be introduced into some of the other British colonies to the decided advantage of those persons who undertake to subdue the native forests, I will proceed to explain it.

"Since it is not every species of forest-tree that contains alkaline salts, or at least in such quantities as to be worth the while of any one to attempt to extract them for useful purposes, it has become a matter of some consideration with parties who calculate upon turning the ashes of the forest-trees to a profitable account, to have an eye to the kinds of timber the soil produces in the greatest abundance, when making a selection of lands in a state of nature, or what is generally called a wild state; for where a great portion of the timber consists of resinous trees, there is little likelihood of turning black-salt-making to any advantage. Many experiments have been made, from time to time, upon the ashes of the sundry varieties of timber (not very scientific or accurate ones, however), for the purpose of ascertaining which sort yields the greatest quantity of alkaline salts; and it is now generally believed the species of elm, which is tolerably abundant in many parts of the forests of Upper Canada, yields rather more than any other sort of native timber. Next to the elm they consider one or two species of ash—the red beech, the black birch, the black maple, and locust-tree—among the favourite sorts of timber to employ in making potash; but nearly every other species of 'hard wood' (a term used in contradistinction to all the varieties of pine, cedar, &c.) will answer to form part of a pile of logs that is intended to be burned, and black salts afterwards extracted from the ashes.

"There is no particular time of the year set apart for the making of black salts, but a dry season is always the most advantageous, as it would not be advisable to allow the wood-ashes to become wet by rain or otherwise, before they are collected and put into the vats. These vats are very often cuts or sections from some hollow tree, instead of vessels made by the cooper, and sometimes the owners do not even go to the expense of putting bottoms in these hollow logs (tops they do not want), but place them upright on the broad-topped stump of some mighty monarch of the forest, and so contrive some ingenious means of collecting the material (lye) from which potash is made. But this is a slovenly plan; because the vessel having no bottom to it, the water which is poured upon the ashes with which the tub is filled passes too quickly through them, and so fails in extracting the whole of the salts. The more skilful potash-makers use four or five large rude tubs, each containing twelve or sixteen bushels of ashes, and a couple of large iron kettles or cauldrons that will boil from thirty to forty gallons of lye each. As soon as practicable, after the piles of logs have been reduced to ashes, the ashes are carefully collected and taken to the vicinity of the 'boiling-camp;' and when there happens to be more than the vessels will hold, the surplus has to be stowed away under cover to avoid exposure to the weather. When a very copious supply of water is poured into the vats, or whatever they may be called, that contain the dry ashes, the alkaline salts will be the sooner extracted, and a couple of days will suffice to extract most part of the salts; but since very weak lye requires a great deal more evaporating (by boiling) in order to obtain a certain quantity of the black salts, the better managers in these matters saturate the ashes no more than is just necessary to extract the salts: and by letting the mass remain several days before the vents are opened for the liquor to escape by, a much stronger lye is produced, and hence the operation of boiling is much sooner over. To some this may seem of little consequence, whether there should be a thousand gallons to evaporate or five hundred only; but it should be borne in mind that when once the boiling process commences, it ought to be continued night and day until it is completed; for since (for the most part) it takes place in the open air, when the kettles are large and the fires are permitted to go out and the liquor to cool, considerable extra trouble is necessary; for vessels placed in the open air and over fires that are blown about by every breath of wind, require far more fuel to bring their contents to the boiling-point than if they had been placed in any ordinary apartment over a fire-place that was exactly adapted to the shape and size of the vessel.

"When the lye has been boiled down to a consistency approaching a semi-fluid form (but the settlers have several plans of ascertaining when it has been sufficiently reduced), the mass is allowed to cool in the bottom of the kettles, where it crystallizes and becomes a tolerably solid substance, but neither white nor exhibiting any transparency; since during the process dust and ashes and smoke have had access to the boiling liquid; and this, in addition to the lye itself acquiring a dark colour from the mixed ashes, charcoal, and particles of soil, gives to the crude potash that dark appearance from which it derives its name, and it is in this state that the farmers, or the parties employed in clearing away the primeval forests of Upper Canada, generally bring their produce into the market. Formerly much of the black salts was sent all the way to Montreal or Quebec, in the state in which it was taken from the kettles of the settlers, and there sold to parties who were at no great deal of cost or trouble in converting it into marketable potashes; but in most of the older and more flourishing settlements there now are persons (principally storekeepers) who are ready to buy it from the settlers, and who have the requisite conveniences connected with their establishments for converting the black salts into either pot or pearl ashes, as may seem to be the best calculated to answer their purpose; when it is afterwards packed in proper casks for the foreign markets, but which it can only reach through the distant markets of the sea-ports above mentioned.

"I have known settlers clear twenty acres of land annually, and yet able to pay the whole of the expenses by the sale of their black salts; while the labour attending the manufacture of this article has been performed by the parties owning the land; but even if persons had been hired to perform it, the expense would not have exceeded a fourth part of the cost of clearing. To be sure, lands that will yield black salts to pay the cost of clearing, must be well stocked originally with the most favourable sorts of forest-trees for yielding salts; and since it is by no means necessary that the wood-ashes should be spread upon the ground as a manure (the maiden soils being sufficiently fertile—either naturally, or through additions of decayed leaves and other vegetable matter), they consequently are accounted of little or no value as regards the future crops the soil may be adapted to produce. Indeed this is frequently so obviously the case, that it is quite a common thing to find settlers, in districts where they neglect making black salts (and yet such as have the reputation of being good managers generally), after reducing to ashes the large piles of timber upon the lands they are clearing, not even going to the trouble of spreading them over the surrounding surface in the immediate vicinity, but contenting themselves with letting the whole remain upon the very place where the logs had been piled together and consumed.

"I have been induced to dwell upon this subject at a greater length than I otherwise should have done, with a view of making this source of profit to new settlements more generally known than it appears to be at present; and not only more known, but more generally practised; and what, to me, seems a matter quite unaccountable, is this,—that throughout the United States, among a people who are confessedly so prone to mix up with their farming pursuits, speculations of various sorts connected with trade, manufactures, and commerce, this plan of turning the clearing of wild land to a profitable account, or at least of reducing the expense to little or nothing, should continue almost universally neglected from one end of the Union to the other. There are, it is true, what go by the name of 'asheries,' in many of the inland country towns and villages of the United States, where both pot and pearl ashes are manufactured; but the owners of these establishments employ only dry and clean ashes, such in fact as are made in the dwelling-houses, which the manufacturers themselves collect in their own carts from house to house, at 4*d.* or 5*d.* per bushel; or if delivered at the ashery by the settlers, a trifle more is usually given."

Although the potash is sold by the settlers in the rough form of "black salts," yet it is almost always purified before being brought to the English market.

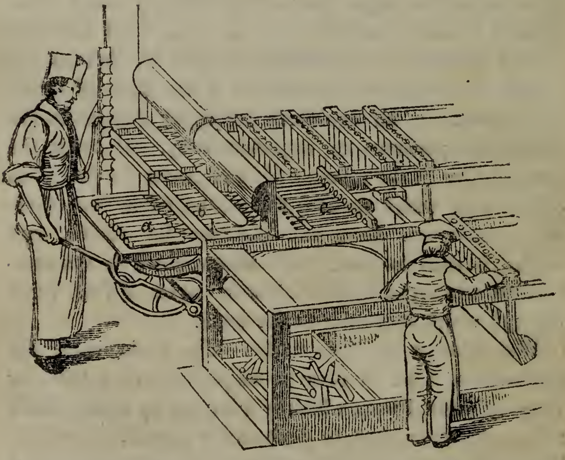
CANDLES.

Let us now turn our attention from the manufacture of soap and its constituents to that of candles, a branch of art exceedingly simple and free from technical difficulties.

Candles can be made from any fatty substance which, at ordinary temperatures, is in a solid state; wax, spermaceti, and tallow being the usual substances employed. That very essential part of a candle—the wick—performs an office which involves a scrap of philosophy not always well understood. The wick is composed of a dozen or more fibres of soft cotton, ranged side by side, and having just sufficient twist given them to make them cling together. The threads are not so close together but that oil, or tallow in a melted state, will ascend between them, by virtue of that capillary attraction which will cause a piece of loaf-sugar to become wet throughout if placed on a wet spot. When a candle is lighted, the heat melts the upper part of the tallow, which then ascends between the fibres of the wick, and furnishes minute streams of combustible matter as fast as the oxygen of the air will consume it in the form of flame. The current of air constantly supplying oxygen to the flame, also performs an important duty. It keeps the outer surface of the tallow cool, and causes the formation of the 'cup' which contains the melted tallow that otherwise would run down and disfigure the candle, and render it unfit for use. The tallow, then, is the combustible matter, and the wick is the series of little tubes through which it ascends to the flame.

Wax candles are thus made:—The wicks being cut and twisted, a set of them is suspended over a basin or vessel of melted wax, which is taken up by a large ladle and poured from time to time on the tops of the wicks. The melted wax, as it flows downwards, adheres to and covers the wicks throughout their length. This is repeated until a sufficient weight of wax has been gathered upon each. After the candles are sufficiently cooled, they are rolled upon a smooth table in order to give them a perfectly cylindrical form, and are then polished.

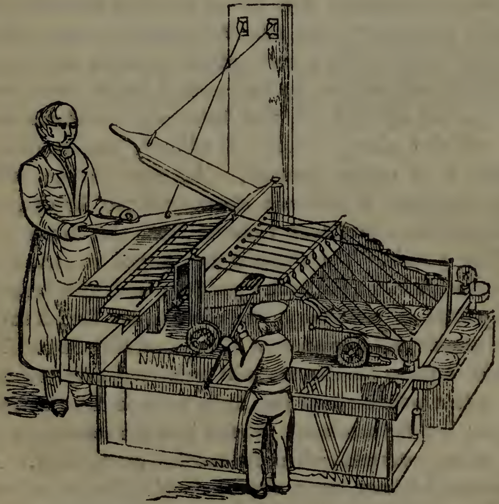
Mould-candles are made in two different ways. It is generally known that candles of this kind occupy a medium rank between wax and 'dip' candles, resembling the former in regularity of shape, and the latter in material. Usually mould-candles are made as follows:—From ten to sixteen cylindrical pewter moulds are placed together in a wooden frame, so that their upper ends ter-



[Mould-candle Machine. *a*, mould candles; *b*, moulds, through which the candles are pushed by the rods *c*.]

minate in a kind of trough common to the whole. The wicks are inserted and kept firmly in their proper places in the centre of each cylinder by strong wires. The frame being then placed with the trough uppermost, the moulds are filled with melted tallow, and are placed in the air to cool, after which the wires by which the wicks have been fixed are withdrawn, the superfluous tallow is removed from the trough, and the candles are pulled out of the moulds.

In a recently introduced mode of making mould-candles, many features of an entirely different kind are



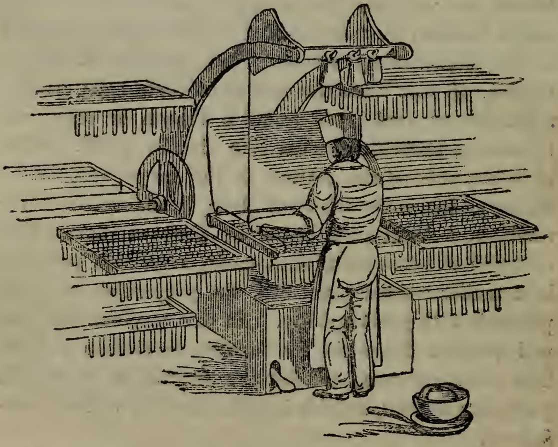
[Machine for cutting the Wicks for Dip-candles.]

observable. The wick, instead of being cut off to the exact length required for each candle, is wound on a reel in lengths of one hundred feet, of which there are as many as there are moulds. In a kind of case or frame are enclosed a certain number of moulds, with a reel of cotton attached to each. A portion of cotton is unwound from each reel, and made to pass through a mould, the lower end of which is only large enough to admit of the passage of the wick, and is held in its place by a pair of forceps. The frame or case is then brought under a kind of box or cistern, into which melted tallow of a fine and pure quality is poured. By turning a handle, the melted tallow is allowed to flow out of as many little holes as there are moulds, and thus the moulds become filled. As the moulds fill, a man pulls the wick in each mould straight and uniform, by laying hold at the lower end. When one set is filled, the frame which contains them is wheeled along a kind of railroad, and another is filled in a similar manner. As soon as the tallow has solidified, a workman disengages the forceps, and scrapes the superfluous material from the upper ends of the moulds. The frame is then turned so as to bring the moulds into a horizontal position; and by a beautiful adaptation of machinery, the candles are forced out of the moulds and thrown on a table in parallel lines. The wicks in these candles are still connected with the coils of cotton wound round the little reels in the frames or cases; but the whole are severed in a few seconds by the attendant workman, when the candles are finished. All the mould-frames move along a double line of railroad, and the whole of the arrangements are so judiciously made that a man and a boy can manage the whole, and produce a surprising number of mould-candles in a short time.

The common 'dip' or 'store' candles are made, as most persons are aware, by dipping the wicks into a vessel containing melted tallow, a small coating of which adheres to the cotton fibres, as do likewise the subsequent coatings to that first laid on. The wicks are prepared in the following manner:—Balls of cotton, each weighing about three pounds, are procured from Manchester or the surrounding district, the cotton being previously made into a loose roving or cord, consisting of a dozen or more threads slightly cohering. These cords (if we may so term them) are of different thicknesses, according to the size of the intended wick; the wick for those candles known as 'eights,' for example, containing thirteen cotton threads. A great number of these balls are carried to the wick-making machine, and put into a box or drawer. A man takes the ends of all these balls, doubles a portion of each cord round a broach or stick, and by a sharp blade (somewhat like that by which tobacco is shred) cuts all the cottons to the proper lengths for wicks, giving to the whole of them, by the action of the machine, a slight twist before he removes them. One stick-full of wicks being thus made, another is prepared in a similar manner; and thus the preparation of wicks proceeds with great rapidity. By this machine one man will prepare the wicks for fourteen or sixteen makers. The wicks for some candles are twisted or spun in a particular manner, but this is effected at the cotton-manufactory.

In making dip-candles by hand, a man takes three broaches or sticks, each containing as many wicks as will suffice for about two pounds of candles, and holding them parallel and horizontal, dips the wicks into a trough of melted tallow. This he does two or three times, and then lightly draws the lower ends of the wicks over a sloping board, to remove the drainings of tallow. These three broaches are hung up for the tallow to dry and harden; another set are similarly treated, and so on. When the first dipping or 'lay' is dry, the coated wicks are dipped a second time; afterwards a third and a fourth; the number of repetitions depending on the size of the intended candles, and being about twelve for the candles known as 'twelves.'

By the machines now employed, however, the opera-



[Dipping-machine.]

tions are surprisingly hastened. In making the kind called 'twelves,' twenty-four candles are hung on each broach or stick; thirty broaches, ranged side by side, form an assemblage called a 'frame;' and thirty-six of these frames are attached to or suspended from the machine, so that the entire number of candles attached to the machine amounts to nearly twenty-six thousand, the whole of which can be made by a man and a boy in ten hours. In the front of each machine is a vessel of melted tallow, and the thirty-six 'frames' are so attached to the machine, that each can, in its turn, be brought over the tallow vessel, and the candles dipped in it. A piece of apparatus called a 'wiping-board' is, after each dipping, ingeniously brought down, by a lever moved by the foot, over the cistern; the ends of the candles are wiped on it, and the board rapidly re-ascends to its former position. There are varieties of dipping-machines, differing somewhat in the mechanical arrangement whereby the 'frames' are brought over the melted tallow, but similar in respect of the great saving in time and labour occasioned by their use. When the candles have been dipped a sufficient number of times (which is known by the use of a kind of steelyard or balance-weight indicating the total weight of all the candles on the machine), and are properly hardened, they are weighed up into pounds, and hung upon strings, the former by men, and the latter by boys, each of whom exhibits great dexterity and quickness in the operation.

Those long and slender candles known as 'rushlights' differ only from common dip-candles in the material of which the wick is made. Instead of fibres of cotton, the wicks are made of dry rushes, which have a loop made at one end by piercing the rush with a sharp instrument, and are then cut to the required length by a gauge or knife. The dipping is conducted much in the same manner as for common candles, except that, from the comparatively small number required, the machine is not employed.

CHAPTER V.

ON COLOURS; OILS; TURPENTINE; RESINS; AND STARCH.

We now turn our attention to a group of substances or commodities which, while on the one hand they involve many points of manufacturing chemistry, are, on the other, of extensive application in the useful arts—we mean white and red lead and colours generally; oils, turpentine, and resinous products. A few examples of these may be taken as illustrations of the whole.

Many of the colours used by house-painters are of mineral origin; indeed most of them are so; the artist making use, in addition, of those of vegetable origin. The oxides of metals are very frequently employed as colours, and some of the salts of metals are so likewise; the metallic form being wholly changed, and superseded by an appearance sometimes earthy and at other times crystalline. Red lead and white lead are two examples of this, forming most useful colours, or bases for colours, in the hands of the painter. There are some factories in the north of England in which both of these are made, in the manner about to be noticed.

Red lead is an oxide of lead, but not the only one. There is one kind, called *litharge*, which results from the refining of lead to obtain the small quantity of silver sometimes mixed with it; and there is another kind, called *minium*, or *red lead*, produced by a wholly different operation. We will first describe the making of litharge, and then that of red lead.

The refining carried on in connection with the lead manufacture, instructively illustrates the difference in value of various kinds of metal. Most lead, after it has been melted from the ore into the form of oblong blocks or 'pigs,' contains a little silver, and the decision of the question whether or not the silver can profitably be extracted from the lead, depends on the ratio between the one and the other. There is a ratio below which the silver obtained would not pay for the wages and other expenses incurred in the extraction, and in such case the refining process is not carried on; while in some instances the lead is sufficiently rich in silver to yield a handsome return for this process. Sometimes it is found, on assay or analysis, that there is only half an ounce of silver in a ton of lead, while some of the rich veins of lead contain more than a hundred ounces of silver to the ton. If it contains five ounces to the ton (the average of the district being about ten), then it is deemed worth the trouble of refining, where operations are conducted on a large scale.

In order to extract with advantage so small a portion of silver, the manufacturer is indebted to an ingenious process, invented and patented within a few years by Mr. Pattinson of Newcastle. The apparatus consists of a number of large cast-iron pots, holding five or six tons of lead each. In these the lead containing silver is melted, and then suffered to cool slowly, while a workman keeps it continually stirred with an iron tool. As it cools, a kind of crystallization takes place; particles or *crystals* of solid lead fall to the bottom, and are withdrawn by a perforated ladle or colander. These solid particles contain less silver than the original lead, while the remaining fluid part is proportionately enriched. The same operation is repeated again and again upon the remelted crystals, and also upon the residual richer portion, until finally the silver is concentrated into 1-10th or 1-20th of the original bulk of lead, while the remaining part of the lead is almost entirely deprived of the precious metal. The rich lead thus produced is then subjected to a process called *cupellation*, which consists in heating the metal in a peculiar furnace to a high temperature, and at the same time exposing it to a blast of air, by which the lead is oxidized and comes off as '*Litharge*;' while the silver, not being so acted upon, remains in a mass or cake of great beauty and purity, often weighing several thousand ounces. A singular and brilliant appearance accompanies this process. When the silver is in a melted state, it absorbs between its particles many times its bulk of pure oxygen gas; this gas, as the metal solidifies, is expelled, and, escaping from beneath the hardening surface of the mass, forces with it the yet fluid metal from below, and forms lively representations or *models* of volcanic operations, leaving the surface covered with beautiful and fantastic concretions of pure and brilliant silver.

The *Litharge* is either used in the making of flint-glass, or in preparing the salts of lead, which are much employed in dyeing and calico-printing; or, being mixed with coal and heated in a furnace, it parts with the oxygen and resumes the metallic form, being then called *Refined* lead.

Red Lead.—This substance is not so absurdly named as 'black lead' and 'sugar of lead,' the first of which contains no lead, and the second no sugar; but still it is not quite a correct name, for it is lead combined with another agent, which totally destroys its customary metallic quality. Red lead, like the litharge which we have just noticed as resulting from the refining, is a combination of lead with the oxygen of the air, but in different proportions, for red lead, or 'minium,' as it is also called, contains a larger quantity of oxygen than litharge to a given quantity of lead.

When melted lead is exposed to the action of the atmosphere, the upper fluid surface gradually combines with the oxygen, and forms a greenish yellow powder. This is the first stage in the manufacture of red lead, and is carried out in the following manner:—There are several furnaces ranged in a row, of the form called reverberating, and of which a familiar idea may be given by comparing them to bakers' ovens. The pigs of lead (after the silver has been extracted from them) are put into the wide mouths of these furnaces, in the proportion of about a ton and a half of lead to each furnace. Flame is then admitted to act on the lead so as to melt it; and then begins the particular process by which the red lead is produced. A man stands before the open mouth of the furnace, as in the adjoining cut, provided with a long rake or stirrer. This stirrer is suspended by the middle from a chain overhead, so as to have greater facility of movement; and the man continually works and stirs the molten mass with this instrument. His object is to let every part of the metallic mass come in turn up to the surface, where it can come in contact with the air. This hot and tedious process is continued uninterruptedly for five or six hours; by which time the lead has lost its

[Red Lead 'Stirring.']

fluidity, its whitish colour, and its metallic lustre, and has become a greyish yellow powder.

It is not possible to convert the whole of the lead into powder by this means, since that which is formed must more or less prevent the remainder from having contact with the air. The contents of the furnace therefore become protoxide of lead mixed with metallic lead. To remove this metallic lead is the next process. The contents of the furnace are conveyed to an adjoining part of the buildings, where 'grinding-stones,' 'settling' cisterns, and tanks point to a very different class of processes. The powder is put into a mill and ground till the lead itself is crushed to a fine state; and the whole is diffused in water in a cistern. The particles of metallic lead, being heavier than the rest, sink to the bottom; while the yellow powder becomes diffused through the water. The water, thus coloured of a bright yellow (for the greenish tinge had been caused by the blue lead mixed with the yellow powder), then flows through a series of tanks or troughs, arranged at such a slope that the liquid may be able to deposit its sediment of yellow oxide as it goes along; and this sediment is afterwards collected and dried.

Here we have a tolerably pure oxide of lead, which is called *massicot;* and by causing this to combine with a still larger portion of oxygen, it is converted into red lead, or minium. To effect this, the yellow powder is again put into reverberating furnaces, again heated, again stirred by a rake, and allowed to gather oxygen from the air for a much longer period than before. It changes its colour from a beautiful yellow to a fine red, passing through all the gradations of orange colour; or rather, this orange tint results from yellow particles and red particles being mixed in the same mass, and in different proportions as the process goes on. When finally removed from the furnace, it is ground a second time to a fine powder, and packed for sale.

In this instance, then, we see that heat and air, acting on metallic lead, convert it into *red lead;* but we shall now find that a different agency converts metallic lead into

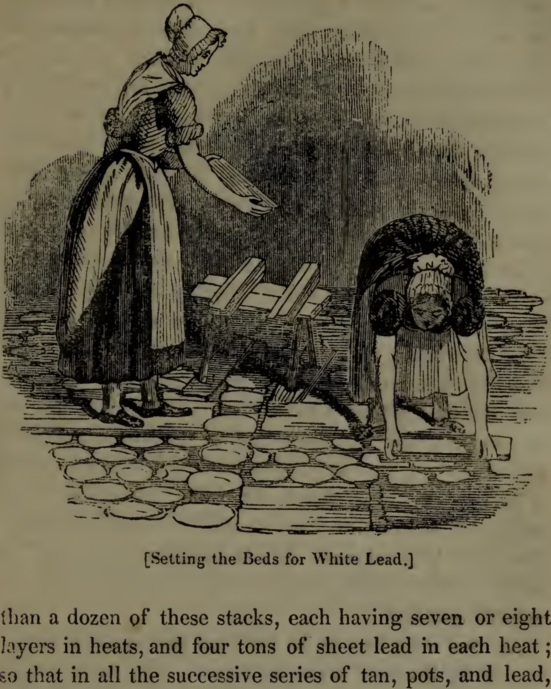
White Lead.—The use of white lead in the arts is rather an humbling instance of the limit to our practical knowledge. Everybody says that white lead is injurious to the painters who use it; yet no one knows either how to do without it or how to remove its deleterious effects on the system. White lead forms the basis of nearly all the pigments used by the house-painter; and it possesses so many valuable properties for this purpose, that it has outlived all the objections made to it, and all the attempts made to supersede it.

There is a very curious circumstance connected with the manufacture, which would almost seem to show that this substance is not necessarily so deleterious as it is often said to be. Most of the processes are conducted by women. The white-lead manufacture is extensively carried on at Newcastle, and we believe that the employment of women in it is pretty general. Why this is the case we cannot say: time was, before Newcastle made the giant strides it has recently made, when the bricklayers' labourers of that town were of the feminine gender; and women may have accustomed themselves to employments generally undertaken by men elsewhere. As to the circumstances in the social condition of the people which lead to the engagement of females in this way, it is a question too wide to be touched upon here, and therefore we proceed at once to the subject more immediately in view.

White lead is a carbonate of lead; and to make this carbonate, many plans are followed; but it will suffice for our purpose to notice the older and most common process.

There are lofty square rooms, in which this conversion of lead into carbonate of lead takes place; and the manner in which these rooms are gradually filled is singular enough. But we must first notice the form into which the lead is brought. In a separate building is a cauldron or open vessel of iron, round which women are engaged. Pigs of lead are put into this cauldron, and melted by a fire beneath. When melted, the lead is laded out of the cauldron into flat iron moulds, whereby thin sheets are formed about twenty inches long, four or five broad, and about an eighth of an inch thick. This the women do with great quickness; one stirring the molten lead to keep the surface clear, others casting the flat pieces, and others removing these pieces from the mould. When a sufficient number is collected, the pieces are put into a box or truck, and wheeled along a miniature railway to a place where they are weighed; and when this weighing is finished, the thin pieces (weighing about five pounds each) are ready to be applied to the next following process.

In the lofty square rooms a series of strata are built up one over another, to the height sometimes of more than twenty feet; and these strata are such as will certainly seem odd to most readers. At the bottom of all is a layer of fine ashes; next upon this is a layer of tanner's spent bark, two or three feet thick; then a layer of earthen pots, about five inches in diameter, and containing each a pint of vinegar; then a layer of leaden plates, six in depth or thickness, laid over the open mouths of the pots; then a layer or covering of boards; next a second bed of spent tan, a second layer of pots containing vinegar, a second layer of leaden plates; and so on, until a 'stack,' as it is called, is built up to the height of more than twenty feet. Each layer of pots, with the tan beneath and the lead above, is called a 'heat,' or 'bed;' and the stack sometimes contains seven or eight of these heats when filled. In one factory we have seen more



[Setting the Beds for White Lead.]

than a dozen of these stacks, each having seven or eight layers in heats, and four tons of sheet lead in each heat; so that in all the successive series of tan, pots, and lead, there must be a mass of pretty considerable weight. The door of each room, if we may call it a door, is as high as the room itself; and each layer of the materials forms a floor on which the women stand and walk, as in the annexed cut, either to empty or to fill the stack. When all the arrangements are completed, the room is entirely closed up, and left untouched for many weeks.

Then comes the inquiry, what takes place in the stack during this period? The spent bark gradually ferments, and in so doing gives forth a considerable amount of heat (about 180° Fahr.), sufficient to cause the vinegar in the pots to evaporate slowly. This vapour is of a compound and acid character, and appears to act upon the thin sheets of lead placed over the pots in the following manner:—The surface of the lead is first converted into an oxide; this oxide is formed into an acetate by the vinegar; and this again changed into carbonate by carbonic acid gas yielded by the fermenting bark. In some factories other liquids are used instead of or mixed with vinegar, and other sources of heat than fermenting tan; and indeed there is some little chemical complexity involved in this change of metallic lead into white lead; but it will be sufficient for our purpose to know that the whole of the arrangements in the 'stack' are for the purpose of causing the thin pieces of lead to combine chemically with carbonic acid and oxygen to form white lead—a substance totally different from the lead whence it was prepared, since it is a white earthy-looking solid, wholly without lustre or metallic qualities.

As the stack had to be built up piecemeal, so now it has to be dissected layer by layer. The upper part of the door or entrance to the room is opened, and access gained to the interior. The women remove the uppermost sheets of lead, then the earthen pots (which have lost a good deal of their contents by evaporation), then a layer of bark, then a layer of boards, then a second tier of lead and of pots, then the next lower layer of bark; and so on, until the stack is entirely removed and the room emptied. All this is done in a stooping attitude, and is so far rather fatiguing; but there is no further difficulty in the matter.

The thin pieces of lead, thus removed from their prison-house, are perfectly white and earthy at the surface; but on examination they are found to be metallic in the centre. The acid gas has penetrated to a certain depth at both surfaces, but not so deep as to convert the whole mass into carbonate. Under this mode of manufacture there is generally about one half of the mass of lead converted into carbonate. To separate this white portion from the metallic lead, so that the latter may be re-melted and the former brought to the state of saleable white lead, is the next operation. The pieces are carried in flat boxes to another building, where there is a pair of revolving brass rollers working in a large vat of water. Each piece is put between the rollers, which are adjusted at such a distance apart that the white earthy matter is broken or crushed off, leaving the thin metallic film nearly separated from it. All alike fall into the water, the blue lead and the white lead; and a number of persons are then employed to rake and stir the mass to and fro. The white lead becomes suspended in the water, and passes through holes in the false bottom of the vessel; while the metallic lead which remains behind is gathered up, to be re-melted and re-cast into thin plates for the stack.

The thick creamy liquid passes from this vessel to various others, where the white lead suspended in the water is brought to a very fine state; grinding-mills, tanks of running water, and systems of pipes and pumps to convey the liquids to different levels, being among the apparatus employed for this purpose. At length, when brought to a state of very fine division, the white lead is allowed to settle to the bottom of the last vessel through which the liquid flows, and is thence removed in a paste-like state. To dry this paste is the next object of attention. There is a stove-room, so highly heated that a person unaccustomed to the employment cannot remain in it many minutes together; the temperature is indeed about 190° Fahr. Throughout the greater part of this stove-room are a number of iron rails or shelves, so placed one above the other as to contain many thousands of flat earthen dishes. Into these dishes the pasty mass is laded, to the extent of about ten or twelve pounds in each; and the dishes so filled are placed upon the shelves in the stove-room (the stove being at the time cold), there to remain till the white lead is quite dry.

White lead is brought into the market in two forms: as a dry earthy substance; and as a kind of thick paint or paste ground up with linseed oil. To prepare this latter kind of commodity is the last process. The white lead is placed in a vessel, together with a given proportion of linseed oil. A stirrer or rake is kept constantly at work in mixing these two ingredients well together into a very stiff paste; and the mass then flows out through a hole into the space between two grindstones or millstones, where it is ground up to a state of perfect smoothness and equality. To deposit this smooth product in casks, and to pack those casks carefully for the market, finally complete the range of processes.

Colours.—It would be almost impossible to enumerate the various substances employed as colours, and the modes by which they are prepared; but in nearly every case there is a compound action of heat and chemical affinity involved in their production. *Vermilion*, for example, is a sulphuret of mercury; and is procured by heating sulphur and mercury together in an iron vessel. Beautiful varieties of yellow and of scarlet are produced by chemical treatment of the ores of *chromium*. *Prussian blue*, we have noticed in a former page, results from a particular mode of employing potash in the alum manufacture. The names of *copperas* and *vitriol* are applied in rather an indefinite way to crystalline colouring substances, which are chemically compounds of sulphuric acid with iron, with copper, and with zinc; and are made by processes more or less analogous to some of those which have engaged our attention.

Oils.—Without dwelling longer on these points we may proceed to speak at once of a class of liquids which give to these colouring agents much of their practical value, viz. *Oils*. There are in many parts of the country *oil-mills*, the operations of which are intimately connected with this matter.

An oil-mill is necessarily rather a dirty place, for the exudation from the seed is of a very unctuous and adhesive quality, and " leaves its mark " upon everything it touches; the odour, too, is unmistakeable, and demands a little courage on the part of those who are unused to it. Yet, as in other cases of the kind, when we get over these preliminary disagreeables, there is much that is ingenious and interesting in the operations carried on.

The chief operations of the oil-mills in this country are the extraction of *linseed* oil from the lin-seed, or seed of the flax-plant. In other countries oil is produced from various sources. Oil exists in the seed of many plants; in the fleshy pulp which surrounds the seeds of other plants; in the kernels of many fruits; and, more rarely, in the roots, the bark, and other vegetable organs. According to the produce of a country, so do the inhabitants procure a supply of oil from one or other of these sources (omitting the animal oils, such as spermaceti, whale-oil, and seal-oil; these being derived altogether in a different way). In Italy and other southern countries where olives grow abundantly, the produce is crushed beneath an edge-millstone, and then pressed to force out the oil, which is prepared in various ways for the different purposes to which it is to be applied. Oil of almonds, a product of limited extent, is procured by shaking the almond kernels in bags, so as to separate the brown skins, and then grinding and pressing them, by which they are made to yield the oil which they contain. Palm-oil we have before stated to be produced from the fruit of many species of palm. Nut-oil is procured from walnuts and hazel-nuts, which, in the warm climates of the south of Europe, contain sufficient oil to be worth the process of pressing.

Without enumerating all the varieties of vegetable oil (most of which are procured by pressure), it will suffice to say that most of the oil pressed in England is either linseed, hempseed, or rapeseed oil; the sources whence they are obtained being sufficiently indicated by their names. Of the hemp-oil, a few details will suffice. It is produced from the seeds of the same plant which yields the fibrous hemp for rope-making. The hemp-plant grows sufficiently well in England to be made an object of agriculture in Lincolnshire and Suffolk; but it is from abroad that we derive the chief supply. When the crop is grown entirely for the sake of the fibre, it is pulled while in flower; but as it is most commonly grown with a view both to the fibre and to the seed, the pulling takes place at two different periods; those plants which are plucked for the fibre are ready first, and are gathered by the pullers, who walk in the furrows between the ridges, reach across to the crown of the ridge, and pluck one or two at a time. In about six weeks afterwards the seed on the remaining plants is ready for gathering, for the sake of making oil: the stalks are pulled and bound up into bundles, and then set up in the same manner as grain, until the seeds become so dry and firm as to shed freely; the seed-pods are next cut off with a knife, and dried on a cloth exposed to the air, under a shed or cover. From the seeds thrashed out of the pods so gathered an oil is procured by pressure, in the proportion of about one part of oil to four or five of seed; and this oil is used to a limited extent for some processes of the manufacturing arts, and in Russia in cookery.

Rape-seed is the produce of a common English plant; and the rural ceremony of a 'rape-thrashing,' as practised in Yorkshire in the beginning of the present century, was a singular example of the half-work, half-holiday system, of which the 'building-bees' and the 'apple-parings' of America are modern instances. When twenty or thirty acres of rape were to be thrashed, all the neighbours for miles round came to assist; and the farmer made ample provisions of meat and drink for his friendly assistants. Every one who came offered a helping hand; and a few were engaged at stipulated wages, to ensure a sufficient supply of labourers. Before the appointed day a flat open place was cleared from stubble and rubbish, to form a thrashing-floor; and on this were laid the rape-cloths, which were strong heavy cloths twenty yards square. The men divided themselves into 'carriers,' 'thrashers,' and 'floor-men,' while the women and boys supplied them with the rape-plants. Canvas carrying-cloths were provided, about six feet square, with poles fixed in two opposite sides in the manner of a roller map; openings being left in the middle between the poles and the canvas for the two men to pass their arms through, one on either side the poles. Operations commenced by the boys holding the carrying-cloths open, while the women filled them with the rape-plants. The carriers then bore the laden cloths to the thrashing-floor, resting the poles on their shoulders, and allowing the cloth filled with rape to hang between them. The rape was then spread out thin on the thrashing-cloths in a circle as large as the cloth would contain, and the thrashers moved continually in this circle, marching with a slow step in pairs and in two divisions, the individuals of each division following one another as closely as the nature of their employment would allow. The floor-men were subdivided into 'layers-on,' 'turners,' 'takers-off,' 'rake-men,' 'riddlers,' &c., each of whom had a prescribed office to fill: the layers-on went first, placing the rape-plants on the ground; then came the first division of thrashers; then the turners, to turn over the plants; then the second division of thrashers; then the takers-off, who with wooden forks shook and threw off the straw. Lastly the rake-men gathered the seed into recesses formed within the circle, where a group of fillers and riddlers were employed in separating the seed from the principal part of the pods and short straws which were beaten off in thrashing; while others put the unwinnowed seed into bags and carried it to the waggon. Towards the close of the day the straw mounted into great heaps; and what with the almost silvery brightness of these heaps, the close phalanx of thrashers brandishing their flails, the cloth-men busily engaged in their various employments, the team drawing off the bags of seed, the carriers carrying the plants to the thrashing-floor, and the hilarity observable among the whole—this scene was described as being one of the most picturesque which the agricultural districts exhibited.—Have modern changes superseded these friendly working-parties?

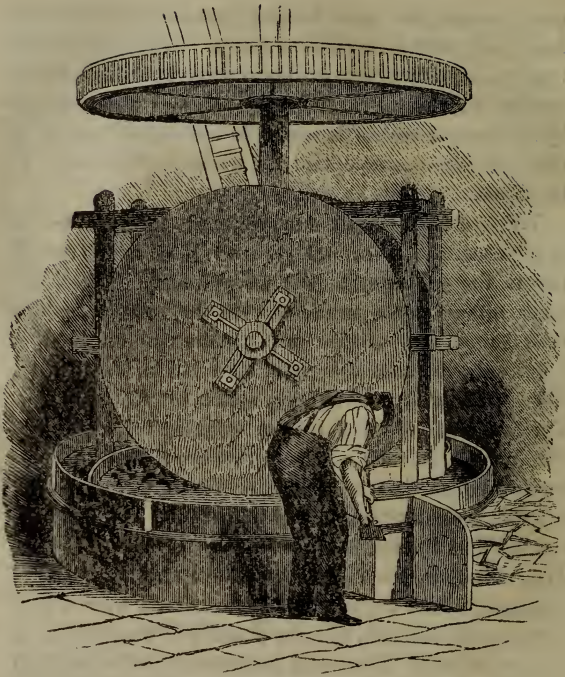
Linseed, the kind to which attention is more particularly directed in England in respect to its oil, is, as we before observed, derived from the flax-plant. As in the case of hemp, the details of culture, when the plant is grown for its seed, are somewhat different from those when the fibre is more particularly the object in view. When, in the latter case, the grown plants have been pulled up for the sake of their seed, they are laid together by handfuls with the seed end towards the south; or else several plants are tied together at the top, and then placed upright with their roots spread out. After the plants have become partially or wholly dried by exposure to the air, they are *rippled*, by which the seeds are separated from them; the ripple is a kind of comb with long wire teeth, through or between which the plants are drawn, whereby the capsules containing the seed are removed from the flax. This being effected, the seeds and pods are spread out thinly upon a cloth to dry in the sun; those seeds which separate from the pods of their own accord are the fullest and ripest, and give least trouble; but those which do not, are lightly trodden on or thrashed, to be loosened from the pods. The whole are then carefully sifted, winnowed, and cleaned from dirt and chaff; and the cleansed seed is laid up till wanted.

Out of such materials, then, is the oil procured which forms the object of attention at an English oil-mill; and we are now in a condition to notice the modes of proceeding.

The kind of press which would serve for the crushing of olives and other soft oleaginous substances would not avail for the seeds of such plants as the flax and hemp. These seeds or grains are exceedingly hard and smooth at their surfaces, and the fragments of their shells, however broken, form little concavities which will retain the oil, unless a far greater pressure is applied than can be obtained by a screw-press. Two forms of apparatus are therefore used — the 'wedge-press,' and, still more recently, the 'hydraulic press.' Formerly the seeds were not in the first instance pressed at all, but were pounded in hard wooden mortars with pestles shod with iron and set in motion by horse or water power, and the triturated seeds were put into woollen bags which were wrapped up in hair-cloths, and then submitted to the wedge-press. This wedge-press acted in the following manner:—The press consisted of a strong block of wood, or a cast-iron frame, in which a long mortise was made; and two bags of seed were introduced in the two ends of the frame in such a manner, that by forcibly driving in some wedges the seed became pressed with immense force, and yielded its oil abundantly. It has been found that the same pressure gradually brought about will not produce anything near so great a force as when exerted by sudden and violent impulses in the wedge, and it is from this circumstance that the wedge derives much of its power.

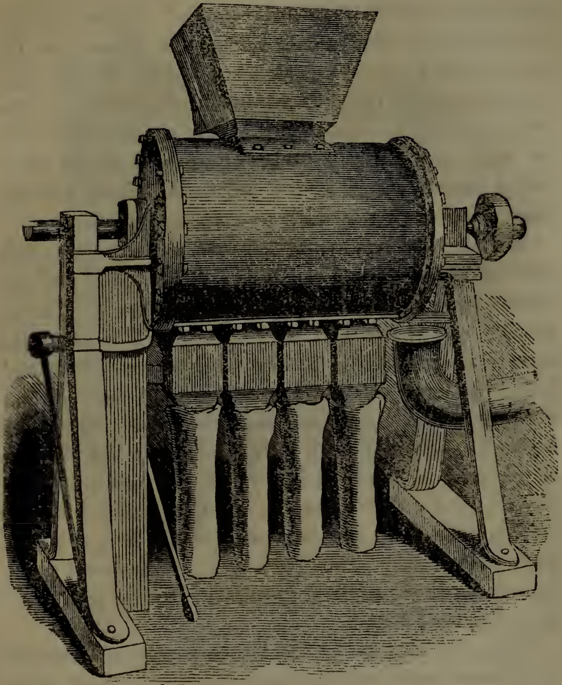
The hydraulic press is now, however, the great source of pressure, and is extensively used in oil-mills (though not to the exclusion of the wedge-press). There are other arrangements preliminary to the pressing, which must be noticed. Before the grinding of the seed, it is bruised; because unbruised seed has a tendency to slide away under the rolling action of the millstone. The bruising is effected by two crushing-rollers, placed side by side, in such a manner that the seed, introduced between them from a hopper or funnel placed above, becomes bruised or crushed by the rotation of the rollers, and falls in a bruised state into a chest placed beneath it. The bruised mass is then transferred to another piece of apparatus, where a pair of edge-stones roll over a bed-stone placed beneath, like the stones of a drug-mill or a gunpowder-mill. The stones (represented in the annexed cut), which are of large size, travel round in a continuous circle of small diameter, rolling over the seed which is placed on the bed beneath. They grind this seed, not only by their weight, but also by a kind of rubbing or frictional movement, occasioned by the outer edge of the stone having to perform a larger circuit than the inner.

The seeds which have been exposed to this double trituration do not assume the form of a dry powder, for the oil which has been partially expressed from them



[Grinding the Linseed.]

during these operations becomes mixed up with the fragments, and the whole together forms a paste. When the manufacturer wishes to obtain ‘cold-drawn’ oil, he at once exposes this pasty mass to the action of the press, by which oil of a very fine quality, but in very limited quantity, is obtained. To obtain the main supply, the paste is heated before being exposed to the press. The



[Crushed Linseed falling into bags.]

heating is effected in different modes in different mills. In some cases there is a small fire-place situated in the corner of the building, and heated by burning charcoal. The seed is contained in a circular copper pan, which is set over the fire, and a stirrer is so adjusted as to keep the seed in motion while being heated. When the seed is sufficiently heated, a door or sluice is opened, and the seed is drawn out into a number of oblong flannel bags, as shown in the cut. In more modern contrivances the seed is heated by steam, instead of by a charcoal fire; but in both cases the seed is kept constantly stirred while being heated, and is drawn out when heated into the bags which contain it while undergoing pressure.

We have said that hydraulic presses are now frequently used for the expression of the oil. The bags of seed are flattened slightly with the hand, and piled up one on another in cast-iron cases, which are placed in the press as shown in the next cut. The force is then laid on, and in a few seconds we see the oil oozing from every pore in the bags, and running down into convenient receptacles beneath. When as much oil is obtained by this pressure as the seed in this form will yield, the pressure is removed, the bags are taken out, and then stripped off the seed, which has by this time assumed the form of a flat, hard, solid cake. This cake is again ground, again heated, and again pressed, by which a further portion of oil is extracted from it.

When the bags are for the last time stripped from the seed (an operation which is facilitated by a simple piece of apparatus sketched in the cut), the latter present almost the hardness and solidity of a board. They are trimmed and brought into a regular form fit for packing, and are then sold as *oil-cake*. This cake is a valuable article to agriculturists, and has at times been sold at a high price; it is employed in the fattening of cattle, sheep, and other animals, for which it seems fitted by the oil

[Bags of Linseed in the Hydraulic Press.]

which it still contains, and which could not be wholly removed by pressure. It is usually given to the animal mixed with some other sort of food, such as hay or cut chaff. On the Continent linseed-cake is sometimes diffused in hot water, and given to the animals to drink, hay and other food being eaten at the same time. Much controversy has arisen among agriculturists and graziers as to the precise value of this kind of fattening food, in reference both to the condition of the animals when fed on it and the manure resulting from the system; but the advantage of using it seems to be very much influenced by the price at which the cake can be purchased.

When the cake is so dry as not to leave enough nourishment for fattening cattle, it is occasionally used as manure; in which case the cake is reduced to powder, and is sown by hand on ground intended for wheat, barley, or turnips; being harrowed in with the seed, and used at the rate of from three to six quarters per acre. It is rape-cake that is thus used, linseed-cake being generally too costly.

The oil, as expressed from the seed, requires very little more attention. It is transferred from the vessels into which it falls, into casks and other receptacles, and is then ready to be applied to some one or other of the numerous purposes for which it is fitted. It is principally as a vehicle for mixing oil-paints that it is used; but there are innumerable branches of the manufacturing arts in which it is extensively employed. Many medicinal preparations, too, derive a portion of their value from the presence of this oil, in a more or less refined or purified state. Linseed-oil, in its usual form, is essentially what is termed a 'fat' or unctuous oil, possessing a property which renders it very slow in drying. To remedy this, which for some purposes would be a great inconvenience, a small portion of the oil made is converted into 'drying' oil, whose distinctive quality is indicated by its name. The drying quality is imparted to the oil by boiling it with sugar of lead, white vitriol, red lead, or some one of a rather numerous list of substances. Common drying oil is often made by boiling linseed-oil with red lead; but the finest kinds are produced by some finer agent, sometimes one or other of the gums.

Turpentine.—From *Oils* we may proceed to *Turpentine*, another valuable aid to the painter. Although distilled for use in this country, yet it is primarily prepared abroad; and the source whence it is obtained so instructively shows the bountiful manner in which nature furnishes useful products, that it may be well to glance at the subject generally.

There is a singular variety in the resinous products of the *pine* and *fir*, according to the species from which they are obtained, and the mode of obtaining them. Some result from a simple incision in the trunk of the living tree; some require a process of heat to obtain them; some are solid; some liquid. The best mode of viewing the matter will be perhaps to take in succession the species which yield the best-known resinous products.

The best *turpentine*, viz., that of Chio or Cyprus, and which gives name to all the other kinds, is not the growth of the pine or fir genus; but all the other kinds, such as Venice turpentine, Strasburg turpentine, and the common turpentine, are produced from this genus. All turpentines are produced by making incisions in the living tree, from which a kind of juice flows out. The Strasburg turpentine is a kind which is produced from the silver fir; and Mr. Loudon's account of the mode adopted by the Italian peasants in collecting it will well illustrate the general way of procuring turpentine.

At about the month of August in every year the pea-

[Stripping the Bag from the Oil-cake.]

sants proceed towards the fir-forests on the Alps. They carry in their hands sharp-pointed pouches called 'cornets,' and tin vessels suspended from girdles round the waist. Thus accoutred, they climb to the summits of the loftiest fir-trees; their shoes being armed with cramping-irons, like spurs, which enter into the bark of the tree, and thus support the wearer. The resinous fluid is contained in small tumours or blisters, under the epidermis of the bark; and the peasant, clinging to the trunk of the tree with his knees and one arm, presses the sharp extremity of his cornet against the little tumours. An incision being thus made, the cornet is soon filled with the clear turpentine which flows from the blister. The man then empties the treasure into the tin bottle slung to his waist, and proceeds to another tumour in a similar manner. When the bottle is full, the turpentine is strained into a large leather or goatskin bottle. This straining is to free the turpentine from the leaves, moss, and bits of bark which may have fallen into the bottle; and this is the only preparation that is given to this kind of turpentine, which is kept in the skin or leathern bottles for sale. Good Strasburg turpentine ought to be clear, free from impurities, transparent, and of the consistence of syrup, with a strong resinous smell and rather a bitter taste. It is employed, as well as the essential oil of turpentine distilled from it, both in medicine and in the arts. The essential oil is distilled with water from the turpentine, and there is left remaining a solid residue which constitutes black resin.

The *larch*, which forms a particular kind of the coniferæ, is the tree which yields the 'Venice turpentine' sold in the shops. Unlike the Strasburg turpentine, this product is obtained from incision in the trees themselves, instead of from tumours or excrescences on the upper branches. When the sap of a vigorous larch begins to be in motion in the spring, drops of turpentine are often seen exuding from the bark; and if the trunk were split, it would in such case be found to contain several deposits of liquid resin, at eight or ten inches depth within the bark. It is in the mountain-valleys between France and

Savoy that this kind of turpentine is principally collected. The peasants of the valley of St. Martin, in the Pays de Vaud, use augers nearly an inch in diameter, with which they pierce the full-grown larches in different places, beginning at a height of three or four feet from the ground, and mounting gradually to ten or twelve feet. They choose, generally, the south side of the tree, and, where practicable, the knots formed by branches which have been broken or cut off, and through which the turpentine easily exudes. The holes are always made in a slanting direction, in order that the turpentine may flow out of them more readily; and care is always taken not to penetrate to the centre of the tree. To the holes thus bored are fixed gutters made of larch-wood, an inch or two in width, and about half a yard long. One of the ends of each gutter terminates in a peg, through the centre of which a hole is bored, half an inch in diameter. This end of the gutter is forced into the hole made in the tree, and the other end is led into a small bucket or trough, which receives the turpentine. A very picturesque appearance is presented in a larch forest, in fine spring weather, by the vast number of little buckets at the foot of the trees, each attached to a tree by a slender tube or gutter, through which the clear limpid turpentine, glittering in the sun, trickles down into the bucket; while every morning and evening the peasants hasten from tree to tree, examining their buckets, taking away or emptying those that are full, and replacing them with empty ones. This scene continues from May to September, during which a full-grown larch will yield about seven or eight pounds of turpentine, which requires no other preparation to render it fit for sale than straining it through a coarse hair-cloth to free it from impurities. If it happens that turpentine does not flow from a hole, the hole is stopped with a peg, and not re-opened for two or three weeks; after which the turpentine is found to have collected in considerable quantity. The Venice turpentine thus obtained is clear, transparent, of the consistence of a thick syrup, with a bitter taste and a strong disagreeable smell. It is employed in making varnishes, in veterinary surgery, and in various departments of medicine.

The common turpentine, yielded by the Carolina pine, is procured in a way somewhat different from either of the above. In the month of January or February cavities are made in the trees, at a few inches from the ground; these are incisions or notches, generally of a sufficient size to hold about three pints of sap, but proportioned to the size of the tree. When these cavities, which in America are called 'boxes,' are made, the ground is raked, or cleared from leaves or herbage. The 'boxes' are intended to receive the turpentine or sap of the tree, which generally begins to flow about the month of March, and becomes very abundant as the weather gets warmer. In order to conduct the sap into the 'boxes,' a notch is made in the tree in the month of March, with two oblique gutters to conduct the flowing sap. In about a fortnight the box becomes full, and a wooden shovel is used to transfer its contents to a pail, by means of which it is conveyed to a large cask placed at a convenient distance. The edges of the wound are chipped every week; and each box becomes filled in about three weeks. Long-continued rains check the flow of the sap, and even cause the wounds to close; and for this reason very little turpentine is procured in cold, damp seasons. The turpentine which solidifies around the edges of the incision is sold as an inferior kind, and a mixture of the two kinds, known as Boston turpentine, is used in the soap manufacture.

Burgundy pitch constitutes another variety of the sap of the coniferæ. This is obtained from the spruce fir. The Burgundy pitch of the shops is the sap of the spruce fir, clarified by boiling in water: hence its production embraces the collecting and the clarifying. In the early part of spring a vertical strip of bark, three feet high by an inch or two in width, is cut from the south side of each tree, as deep as, but without wounding, the soft wood, since it is between this soft wood and the bark that the sap flows. The lower part of the incision is at about two feet from the ground, and is cut inward so as to form a kind of cell or recess. As soon as the sap is in motion, the sides of this groove begin to be slowly filled with it; and when filled, the contents are scraped out with a hook-bladed knife. The resin (for it may more properly be called so than pitch or turpentine) is put into a conical basket or scuttle made of the bark, and kept till wanted for manufacturing.

In order to bring this resinous sap into the commercial form of Burgundy pitch, the peasants in the south of France prepare large cauldrons, into which a little water is poured. The resin is gradually added to the water, till the cauldron is four-fifths filled. A gentle fire is then lighted below, which is gradually augmented till the water boils, and the resin is all melted. The contents of the cauldron are next poured into a bag made of coarse linen, which has been previously wetted, and subjected to slight pressure. The resin flows pure and clear into small casks made of fir-wood; and in this state it is the yellow Burgundy pitch sold in our shops. In general, one hundred pounds of resin, as collected from the tree, yield fifty pounds of Burgundy pitch. Trees grown in fertile soils are said to yield a greater proportion of resin than those grown in poor soils; and the pitch is of better quality when the resin has been collected in a hot dry summer, than in a cold and humid one. A strong and vigorous spruce fir will yield, every second year, from forty to fifty pounds of congealed resin; and this may be collected for twenty or thirty years, if no value be set on the tree except for its resin; else it must be cut down sooner, for it is found that the wood of a tree becomes much deteriorated after the sap has been drawn from it.

Resin.—Thus it will be seen that all these resinous products are obtained by making incisions in the living tree. The common resin of the shops, however, is not exactly a natural exudation, for it is the solid residue obtained by distilling common turpentine. Turpentine consists, in fact, of two substances—an essential oil and resin; and the process which yields the essential oil at the same time yields the resin. When the turpentine is distilled, the oil comes over, and the resin is left behind: if the distillation is continued to dryness, the residue is 'black resin;' but when water is mixed with the turpentine while yet fluid, and incorporated with it by agitation, the solid residue of the distillation is 'yellow resin.'

Tar, Pitch, and *Lampblack.*—Besides the resinous products obtained from the living tree, there are others of a peculiar kind obtained from it after it is cut down. These are *tar, pitch,* and *lampblack.* All the tar of the southern states of America is made from the dead wood of the Carolina pine; consisting of the trees which have fallen from natural decay, or from hurricanes, or fires, of the summits of those which are felled for timber, and of limbs broken off by the ice that sometimes overloads the trees. When a pine-tree is dead, the sap-wood decays, but the heart-wood becomes surcharged with resinous juice, which is productive of tar at any period for many years after the vitality of the tree has ceased.

The mode of preparing tar from this tree in America is as follows:—A kiln is formed in a part of the forest abounding in dead wood. The wood is collected, stripped of the sap-wood, and cut into billets two or three feet in length and about three inches thick, a task which is rendered tedious and difficult by the numerous knots with which the wood abounds. The next step is to prepare a place for piling the billets, and for this purpose a circular mound is raised, slightly declining from the circumference to the centre, and surrounded by a shallow ditch. The diameter of the pile is proportioned to the quantity of wood which it is to receive, and in the middle is a hole, with a conduit leading to the ditch, in which is formed a receptacle for the tar as it flows out. Upon the surface of the mound, after it has been beaten hard and coated with clay, the wood is laid radially round in a circle. The pile, when finished, may be compared to a truncated cone, ten or twelve feet high, and from twenty to thirty feet in diameter. The pile is strewed over with pine-leaves, covered with earth, and held together at the sides by a slight band. A fire is then kindled, not at the bottom of the pile, for the whole mass would soon be rapidly ignited, and the tar would be consumed instead of distilled—but at the top, whence the fire penetrates slowly downwards towards the bottom with a slow and gradual combustion. It is to retard the rapidity of combustion that the covering of earth is laid on the pile. As the wood consumes, the tar flows from it, and by the end of eight or nine days a hundred barrels of tar may have flowed into the ditch, from which it is emptied into pine casks containing thirty gallons each.

In Scotland tar is sometimes extracted from the roots of the Scotch pine, in a rude manner, for local purposes. The country-people having hewn the wood into billets, put them into a pit dug in the earth. When the billets are ignited, a black thick matter runs from them, which falls to the bottom of the pit, and constitutes tar. The top of the pit is covered with tiles, to keep in the heat, and there is at the bottom a little trough out of which the tar runs like oil.

It is, however, from Sweden and Russia that the main supply of tar is obtained; the species of pine which yields tar in the greatest abundance being there plentiful. Mr. M'Culloch states that more than a hundred thousand barrels of tar were imported from Russia and Sweden in 1831.

Pitch bears nearly the same relation to tar that resin does to turpentine: it is the solid residue obtained by evaporating or distilling tar, and is obtained in various ways, according to the nature of the pine or fir whence it is procured.

Lampblack is the *soot* of burned tar. In France they have lampblack-furnaces, in which a chimney carries off the smoke from a fireplace into a chamber which has an opening in the roof. Over the opening is placed a flannel bag, supported by rods of wood, in the form of a pyramid, and composed of four pieces of coarse flannel sewed together. The best lampblack is made by burning straw through which tar has been strained. The straw and tarry refuse are put into the stove, and kindled. The smoke passes from the stove through the chimney into the chamber, where it deposits its soot on the walls and on the flannel bag; the soot is detached by striking the outside smartly with a stick. The flannel pyramid acts as a filter to the lighter part of the smoke, retaining the soot, and permitting the heated air to escape into the atmosphere. The door of the chamber is then opened, and the lampblack, being swept out, is packed in small barrels made of the wood of the spruce fir, for sale. Lampblack seems to have acquired its name from a mode of producing it sometimes adopted in France. Black resin is, in such cases, burned in a kind of lamp, having a tin tube attached by way of chimney; the end of the tube is fixed in a close box, having an opening in the top surmounted by a flannel cone.

It will thus be seen that—disregarding the common commercial names applied to the substances—the resinous products of the pine and fir may be classed as of five kinds: viz., the *turpentine*, or juice of the living tree; the *resin*, or solid residue obtained from the turpentine; the *tar*, or juice of the dead tree; the *pitch*, or residue of the tar; and the *lampblack*, or soot obtained by burning any of these.

The turpentine comes over to this country as a thick semi-fluid mass, in barrels, and is separated into a solid (resin) and a liquid (oil of turpentine) by a process of distillation, carried on at the 'turpentine-works.'

Starch.—Different as may seem to be the sources whence we obtain these several oils, turpentines, and resins, yet they are all of vegetable origin; and we might extend our details so as to include many other vegetable substances of analogous origin. It may, however, suffice to select *starch* as a subject for a few details.

Starch is a peculiar component part of vegetable substances, bearing a curious relation to sugar and to alcohol. Starch, sugar, alcohol or spirit, and vinegar, are all composed pretty much of the same ingredients; and by the processes of malting, mashing, distillation, and acetification, the same grain of corn may be made to yield any one of these very different products. We here speak of starch from grain, but it exists in many different kinds of vegetables. For instance, it exists in the seeds of nearly all kinds of corn; in tap-roots; in potatoes and other tuberous roots; in the stems of palm-trees, and many other kinds of plants; and in many species of lichen. The nature of the starch itself is not less remarkable than the diversity of the sources whence it may be obtained; it is always mixed with other chemical principles, from which it is separated when required to be used simply as starch. It consists of very small roundish white granules, which are generally lodged in the cells of the cellular tissue. These granules differ in size, often in the same seed or plant, being smallest near the circumference of the containing plant. Each granule consists of a membrane, often beautifully marked, and containing a transparent colourless material resembling gum. The membrane is insoluble in cold water, but is soluble at a temperature of about 160° Fahr.

Starch and gluten form the two main ingredients in the flour or meal of which bread and pastry are made; and it happens fittingly that the kind which is best suited for making bread is not that which is most appropriate for starch. Pure starch, though a jelly-like substance when mixed with water, is rather indigestible; and flour which contains a large proportion of starch in relation to the gluten, is not well fitted for making bread. The best bread is made of flour which contains the greatest proportion of gluten; and the quality of bread is apt to be varying from the circumstance that the relative proportions of starch and gluten differ not only in the different kinds of corn, but in the same species or variety, according to the season when they are sown, or the manure which has been applied to the land. Sir Humphry Davy found that in spring-grown wheat, one hundred parts yielded seventy of starch to twenty-four of gluten; while autumn-grown wheat yielded seventy-seven of starch to nineteen of gluten. It has been observed by a practical agriculturist, that "were a scientific system of agriculture to prevail in this country, one kind of wheat, treated with proper manure, would be raised and sold exclusively to the starch-manufacturer; while another kind, treated with its proper manures, would be raised for and sold only to the baker."

Rice is very rich in starch, in comparison with the gluten which it contains. It is said that Carolina rice is more abundantly supplied with it than any other grain, insomuch that there is not more than three or four per cent. of gluten with it. That potatoes contain starch may be made readily visible by the following simple process:—Rasp or grate a potato to fragments over a sieve; pass a current of water over the raspings, and this water will pass through the meshes of the sieve in a milky state; let the water remain stationary some time, and a starchy deposit (more or less mixed with other bodies) will appear at the bottom of the vessel. The combination of gluten with the starch in flour is not recognisable by the eye, but the separating of the two may be very readily effected by the following method:—Make up a stiffish paste of flour and water; leave it at rest for a time; and then carefully and gently knead it between the fingers, while a current of water is flowing on it; the water will wash away the starchy particles, leaving behind a tenacious elastic substance which constitutes gluten.

For the practical purposes of commerce, starch is generally prepared from wheat, and there are different modes of proceeding, one of which is as follows:—The grain, sifted clean, is steeped in water until it becomes swollen and soft; after removal from this water, it is immersed in clear warmish water, and then put into bags, which bags are exposed to strong pressure. This pressure forces out the starchy particles into water; and the water being removed and replaced by clean, still more of the milky liquid is prepared, and the moistened grain loses pretty nearly all its starch. Instead of the pressure, the grain is sometimes crushed under vertical grindstones, or between rollers, and the starch washed out from the fragments. The milky liquor, by whichever method obtained, is poured into large cisterns, where it is allowed to settle and deposit its starch. The surface-liquor is poured off, new water added and stirred up with the starch, a second settlement allowed, a second removal of the surface-liquor, and so on several times, until nearly all the foreign ingredients, such as gluten, sugar, gum, and albumen, are washed out and separated from the starch. After the final deposition of sediment, there appears on the surface a thin layer of gluten and albumen, called 'slimes,' which is removed, and used for feeding pigs or oxen. The starch beneath is in layers or strata of different quality, the particles first deposited being purer than those at the surface; and by a dexterous contrivance these different qualities are removed one by one, and permanently separated. After being again mixed with water and passed through a fine sieve, the starch is laid on linen cloths in wicker baskets, where it is allowed to dry gradually. The solid starch is then cut into pieces, and placed in a warm room or stove to dry.

Another mode of conducting the manufacture exhibits many points of difference from the above. The wheat is first crushed between iron rollers, and steeped in as much water as will cover it. Being thus allowed to remain several days, the mixture ferments, and the starchy particles by degrees fall to the bottom. After a subsequent fermentation in another vessel, the starch is separated by a sieve from the bran with which it had become mixed, and is afterwards allowed to settle for several hours in square frames or cisterns. The surface-water is let off through taps or cocks in the side of the vessel; the 'slimes,' or thin mixture of gluten and albumen, is removed; the washing with water and the deposition of sediment are again repeated, and the same series goes over two or three times. After this the starch receives the blue colour which most kinds present, by having a small quantity of smalt mixed up with it. The starch is then transferred to oblong wooden boxes or trays, which are pierced with holes and lined with thin canvas. In these boxes it remains to drain and solidify, and is afterwards turned out in a solid compact form. The mass of starch is broken or cut up into pieces four or five inches square, and the pieces are placed upon a flooring of very absorbent bricks, where they very soon dry. The drying in a stove, the scraping of the pieces with a knife, the packing in paper, and the final drying of these packages, complete the series of operations.

There are many modifications of the processes, followed by different persons and in different places; but in all of them the separation of the starch from the other component parts of the grain is brought about by pressure, bruising, or rubbing, aided subsequently by fermentation, washing, straining, and drying. There is a 'patent starch' made of Indian corn, and many other varieties of starch, for which the credit of more or less excellence is obtained; sometimes it is a new kind of seed or root which is brought into use for this purpose; sometimes a new modification of the process of manufacture; at other times a new arrangement of apparatus; but the broad principles are pretty much alike in all. As a further example, we may notice the mode of making potato-starch for sale. The potatoes, after being well washed in a cylindrical cage, are brought to the state of a pulp by means of a rasping-machine, consisting of a roughened hoop or cylinder so placed as to grind the potatoes to fragments while it is revolving. The pulp (which is wetted while being rasped) falls into a vessel beneath; and with a machine worked by two men, two or three tons of potatoes may be reduced to pulp in a day. This pulp, by washing, stirring, settling, drying, &c., is made to yield its starch, which, by a well-managed process, amounts in quantity to from fifteen to twenty per cent. of the weight of the potatoes used.

Some of the calico-printers use a kind of stiffening material or starch, which they call British gum, and which was brought into use on account of the high price of gum-Senegal. This British gum is prepared from wheat-flour, and is a kind of medium between common starch and common flour-paste.

CHAPTER VI.

ON THE PORCELAIN AND POTTERY MANUFACTURES.

In this chapter we will take up another department of manufacture, illustrative of the chemical agency whereby crude materials are brought into a homogeneous form, and thence brought to those useful states which are so familiar to us in every-day life: we allude to *porcelain* and *pottery*, a kind of manufacture chemical and mechanical by turns. We will first notice the porcelain manufacture properly so called, as carried on at Worcester, Derby, and other places; and then the larger and more commercially important pottery manufacture, as associated especially with the Staffordshire district.

Porcelain.—Those among our readers who may have witnessed the remarkable "Chinese Exhibition," cannot fail to have observed the sumptuous specimens of *porcelain* there deposited—the vases, jars, cups, and other vessels; and may then have conjectured whether or not England can produce specimens equal to these. China has, by a sort of prescriptive right, been deemed the land of porcelain, the country whose inhabitants occupy the first rank in the production of this most delicate, chaste, and elegant semi-transparent material. Thanks to the inquiries and ingenuity of travellers, manufacturers, and men of science—who have discovered the nature of the principal substances employed by the Chinese, the localities in which they may be found in Europe, and who have employed the services of painters far more skilful than any to be found in China—our country now produces specimens of porcelain possessing all those claims to admiration which the "Celestial Empire" has put forth for its manufacture, and—in respect to pictorial embellishment—others in which our Asiatic friends cannot for a moment share.

Everybody knows that porcelain is the same material as that which is commonly termed 'China' (a name which in itself does homage to the original producers of the substance), but the meaning of the name is not so well known. One authority* says—"The Portuguese traders were the means of introducing the fine earthenwares of China into more general use in Europe; and the name assigned to the fabric, as distinguishing it from the coarser descriptions of pottery of domestic manufacture, was most probably given by them—*porcellana* signifying, in the Portuguese language, a cup;" while another authority† states—"It has been satisfactorily shown by Marsden, that the word porcelain, or *porcellana*, was applied by Europeans to the ware of China from the resemblance of its fine-polished surface to that of the univalve shell so named; while the shell itself derived its appellation from the curved or gibbous shape of its upper surface, which was thought to resemble the raised back of a *porcella*, or little hog." Leaving the reader to select between the 'cup' and the 'little hog,' as the forerunner of the name, we will quit this matter, and describe the general arrangement of a porcelain manufactory.

First, there is the building in which the crude materials are brought into a plastic or working state. Here we see a ponderous circular stone, many tons in weight, working round in a circle on its edge, and crushing beneath it the stony ingredients of the porcelain. Then, in another part of the building, is a circular vessel, provided with a stirring apparatus, for further preparing the substances by the aid of water. The mixing-room, in another place, contains the vessels in which the pounded ingredients are worked up into a smooth kind of clay, fitted for the purposes of the workman. Following the prepared material to the hands of the workman, we visit the 'throwing-room,' where the remarkable process of forming circular vessels is conducted. This is a long and busily occupied shop, containing a great number of men employed as we shall describe presently. Kilns in great number are disposed conveniently, with respect not only to the 'throwing-room,' but to the other workshops; for there are 'biscuit-kilns,' 'glaze-kilns,' and 'enamel-kilns,' according to the state of the process in which heat has to be applied to the ware. Various rooms, called 'placing-room,' 'dipping-room,' 'white-ware room,' 'modelling-room,' 'moulding-room,' 'pressing-room,' &c., are disposed round the open area, for the prosecution of various processes in the course of the manufacture; to which succeed others known as the 'painting' and 'burnishing' rooms, in which those elaborate decorations are given to the manufactured article which form one of the most marked features of distinction between it and common pottery-ware. Then we come to the warehouses in which the finished product is stored. Lastly, there are shops, drying-rooms, and kilns, for the manufacture of the 'tessellated tiles,' which are now becoming so extensively used.

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* 'Lardner's Cyclopædia.'

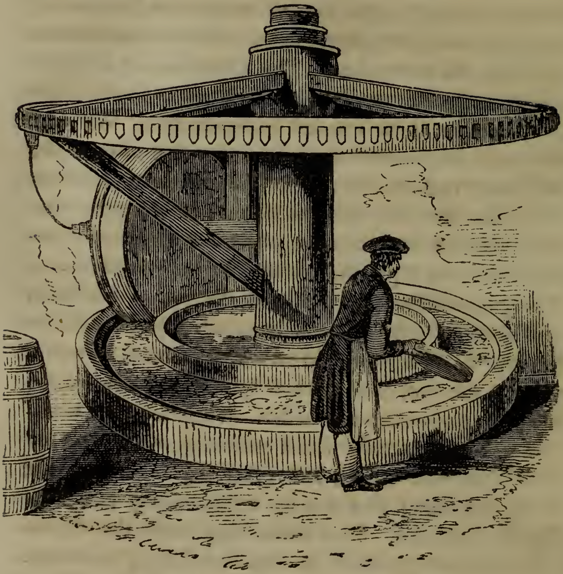
† Davis: 'The Chinese,' chap. xvii.

We have glanced at the buildings, and now let us glance at the workmen, and the remarkable processes by which the costly specimens of porcelain are produced. The rough ingredients, too, must have a passing notice.

The ingredients to form porcelain may to many persons seem rather strange. They consist of common flint, flint in the calcined state, Cornish stone, Cornish clay, and calcined bone, all ground and mixed together with water, so as to form a beautifully fine and plastic clay. Numerous and intricate have been the researches into the respective value of different kinds of material, and the particular quality which each one gives to the porcelain. The clay employed, as its name imports, is brought from Cornwall, and is found to possess qualities wanting in most other kinds of English clay. For the commoner kinds of pottery, clay brought from Dorsetshire and Devonshire is largely employed; but for the more exquisite specimens of porcelain this Cornish clay is preferred. Until about a century ago, the strangest views were entertained in Europe respecting the composition and nature of Chinese porcelain; and it was not till after many researches that Réaumur found that the mixture of the two peculiar kinds of earth found in China, called *pe-tun-tse* and *kao-lin*, produced porcelain. It then became an object to discover whether any earths similar to these existed in Europe; and at length Mr. Cookworthy, about seventy years ago, discovered in Cornwall two kinds of earth which nearly answered the desired character. From that time to the present various improvements and additions have been made in the ingredients employed, with a view to produce a porcelain possessing hardness, strength, firmness of texture, whiteness of colour, and a capacity of receiving and retaining colours and gilding on its surface. The Cornish clay is by far the most costly clay employed in such works; but for the finer porcelain it is deemed indispensable. We may perhaps say, in accounting for the respective value of the ingredients, that the clay gives the plastic or working quality, the flint imparts the vitreous or strengthening quality, and the bone aids in producing the semi-transparency for which porcelain is so deservedly admired.

The ingredients have different degrees of hardness, but all must be reduced to an impalpable powder before being mixed. They are laid on a circular bed, as represented in the cut, and ground by the pressure of the bulky and ponderous stone roller. They are then transferred to a large circular vessel containing water, and by means of stirrers, sieves, and other appliances, brought into the condition of a creamy liquid, totally free from any gritty particles. It is astonishing to see the degree of fineness thus produced, as manifested by the extreme minuteness of the meshes or interstices of the sieve through which everything must pass before being deemed fitted for the manufacture.

Various depositories or receptacles are provided, in which the ingredients are placed separately during the course of their preparation; and from these they are conveyed to the 'mixing-room,' where they are combined together. Here the experience and judgment of the manufacturer are brought into operation: he has to determine not only the number and kind of ingredients which will produce a ware fitted for service, but also the proportions in which these ingredients are to be com-



[Grinding the Flint, Clay, &c.]

bined. It is not improbable that each eminent firm has a recipe peculiar to itself, as is known often to be the case in the glass manufacture, and many other manufactures in which several ingredients are employed. The mixture presents the appearance of a kind of drab-coloured liquid, which is then evaporated to a certain degree of thickness or stiffness by heat applied beneath it. In short, it is by the agency of heat that the cream-like liquid becomes a plastic workable clay, fitted for the hands of the potter. Constant attention is necessary throughout this process, to equalize the rate of evaporation and to retain the ingredients in perfect combination while it is going on.

To the 'throwing-room' and the 'potter's wheel' we now direct our attention, where a process is conducted which has never failed to excite the astonishment of a spectator who witnesses it for the first time; nay, there are many who find the comprehension of the process almost as difficult after many visits as after the first. Never does any one agent appear a more complete master over another than the potter is of his clay: he seems as if he could do anything, everything, with it. At one moment his mass of clay is a shapeless heap; at another a circular cake; then a ball; then a pillar or cylinder, hollow or solid; then a jug; then a basin; a sudden turn converts it into a bottle, or a plate, or a saucer. His hands work and form the plastic material with a rapidity almost inconceivable; and we often doubt where the clay seems to come from, and whither it goes, when one form is being exchanged for another. It is true that, in practice, the potter does not give all these several forms to one individual mass of clay; but a visitor has frequently an opportunity to see that the man *can* do so. What a pity, some may say, that such an elegant process (for such it assuredly is) should be thrown away upon wet dirty clay! but in truth the peculiar state of the clay is the very circumstance which gives to the potter such a command over it. Let us look at the arrangements of the potter's shop before we describe his operations.

Why such a room should be called a 'throwing-room,' or why the formation of circular vessels should be called 'throwing,' it does not seem very easy to determine.

There is a circular motion in pottery-throwing, and also in silk-throwing; but why the same term should be applied in both cases, or why applied at all, we do not see. We believe, however, that 'throw' is a provincial name for a lathe; and if so, an explanation is easily provided, by considering the potter's wheel as a lathe or throw. The throwing-room, however, be its appellation good or bad, is a room containing a great number of benches and pieces of apparatus, at which men are employed making circular articles of soft porcelain.

Scarcely any other machine has lived so long and undergone so little change as the 'potter's wheel.' On the Egyptian monuments, and on other records of antiquity, there are representations of the potter's wheel similar in all the essential particulars to those of our own day; indeed, nothing can be more simple than the construction. In the potter himself, and not in the wheel, lies the merit of the work executed. The potter sits on a kind of stool or bench, immediately behind a small circular whirling-table. His knees are placed one on each side of the central support of the machine, so as to give him a command over it. This, which we have called the whirling-table, is simply a circular piece of wood, whose breadth is sufficient to support the widest vessel that is to be made: it is fixed on the top of a vertical stem or shaft, so that if the shaft be made to rotate, the piece of wood must rotate likewise. The apparatus is rather below the height of a common table. The clay which is to be formed into a vessel is put upon the circular board, and there remains till fashioned; the board and the shaft beneath being made to rotate horizontally, while the potter with his hands gives the form to the mass of clay.

Every potter, or ‘thrower,’ is attended by two boys, who are called the ‘ball-maker’ and the ‘wheel-turner.’ The former of these has before him or near him a mass of prepared clay, having precisely the quality and consistence required for the potter’s operations. He separates the clay into smaller masses, each suited to the manufacture of one particular kind of vessel, and works it up into a rude kind of ball, convenient to be handled by the thrower. He is in every way the servant or helper to the thrower. The services of the ‘wheel-turner’ depend on the manner in which the circular piece of wood is made to rotate. In the early state of the porcelain manufacture in England, the perpendicular shaft beneath the board was put in motion by a wheel provided with spokes, which the ‘thrower’ moved with his foot; the labour, however, was so great, that this method became unsuited to the production of large articles. Another method in past times was, to have a crank in the middle of the shaft, with a long rod working upon it, and motion was given to the lathe by the rod being pushed backward and forward. The customary mode at the present day is, however, to have a rope passing from a pulley upon the perpendicular shaft to a large wheel at a distance, which wheel is turned by a boy under the directions of the ‘thrower.’

With this very simple kind of lathe, and with a few small tools still more simple, does the workman proceed to fashion all those articles of porcelain which are circular in their form, whether cups, basins, or vessels of any other kinds. When the shape is too diversified to be deemed circular, other modes of formation must be adopted, of which more hereafter. Let us suppose, as an example, that a hemispherical basin is to be formed. The man places a mass of clay, in size and consistence suited for the purpose, upon the bed of his lathe or wheel, striking it down rather forcibly as a means of making it hold firmly to the wood during the process of formation. He gives directions to his 'wheel-turner' to set the machine in motion, and then forms the shapeless mass into a vessel, chiefly by his hands. With his hands, wetted in an adjacent vessel of water, he presses the clay while rotating, and brings it into a cylindrical form; this cylinder he forces again down into a lump, and continues these operations—squeezing the clay into various shapes—until he has pressed out every air-bubble from the body of clay, a precaution of very great importance. Then pressing the two thumbs on the top of the mass, he indents or hollows it, as a first germ of the internal hollow of the vessel. Once having the least semblance of a cavity within, he proceeds with a rapidity almost marvellous to give both the outward and the inward contour to the vessel. With the thumbs inside and the fingers outside, he so draws, and presses, and moulds the plastic material, as to give to the outside a convexity, to the inside a concavity, and to the whole substance a uniform consistency, without breaking the clay or disturbing the circular form of the vessel. It will be seen on a moment's consideration that this circular form is due to the rotation of the clay, while the fingers and thumbs are stationary, just as a turner holds his cutting-chisel stationary while the piece of wood is rotating.

During the pressure of the hands upon the clay, a minute change in the amount or direction of the pressure would transform the basin into a saucer, or into any other vessel whose degree of curvature is very different from that of a basin. The oddness of these transformations might often make a spectator smile, were not his admiration excited by the cleverness and dexterity of the workman who produces them. According to the shape and size of the vessel, the 'thrower' requires the wheel and the mass of clay to rotate with varying degrees of velocity, in which he instructs his 'wheel-turner.'

The general contour of the vessels, inside and out, is given by the thumbs, fingers, and palms of the hands. But as this could not insure accuracy sufficient, the workman is provided with small pieces of wood called 'profiles,' or 'ribs,' each of which is shaped in accordance with either the exterior or the interior of some particular kind and form of vessel. Holding one of these 'ribs' in his hand, and applying it to the surface of the clay, the workman scrapes off the superfluous portion at any protuberant or misshapen part, and makes the whole circumference conform to the shape of the rib. The fragments thus removed, technically called 'slurry,' he throws aside among the unused clay. If a number of vessels are to be exactly the same size, the workman sometimes fixes pegs in the stand on which the clay is placed, which act as a guide to him in regulating the diameter to which the clay is to be expanded, and beyond which it must not reach. When the vessel, by the aid of the hands and the small working tools, is formed, it is cut from the supporting piece of clay or from the board by means of a piece of brass wire, much in the same manner as barrelled butter is cut into slices, and the newly-formed vessel is placed on a board or shelf to dry.

In this manner vast varieties of vessels are formed, comprising all those which present, both on the exterior and the interior, a uniform circularity. And, indeed, not only are vessels thus formed, but masses of clay are similarly brought into a cylindrical form, as a nucleus from which ornamental articles may afterwards be produced at the turning-lathe. Within the last few years the use of porcelain has greatly extended, in relation to articles both useful and ornamental. Candlesticks, taper-stands, fancy baskets, door-handles, finger-plates, and a host of other articles, are now made of this material; and if the form is such as can be given by the lathe, a mass of clay is first worked by the hand into something like a cylindrical shape, as a preparative for the operations of the turner.

The operation of *turning* these articles is effected very much in the same manner as the turning of wood. They are allowed to remain until, by the evaporation of moisture from the damp clay, they have acquired a degree of dryness which is known among the workmen as the 'green state,' in which state the shaping and smoothing of the surface are better effected than when the clay is either damper or drier. As a turner in wood can produce an internal cylindrical cavity as well as a circular exterior, so can the porcelain-turner; and it is in this way that candlesticks and similar articles are brought to the required shape.

We have now, in supposition, made circular vessels, and turned them to the required shape and smoothness. But before we follow them through their subsequent progress, it is desirable to witness the production of those articles which neither the potter's wheel nor the lathe will produce; articles which exhibit in an especial degree the magnificence and delicacy of the finer kinds of porcelain. This will take us to the workshops of the 'pressers,' the 'mould-makers,' and the 'modellers;' for the decorated articles are produced by pressing or by pouring clay into moulds, which moulds must previously be made from models, and which models must have been before formed by hand. Hence the modeller is the all-important workman whom we must first visit.

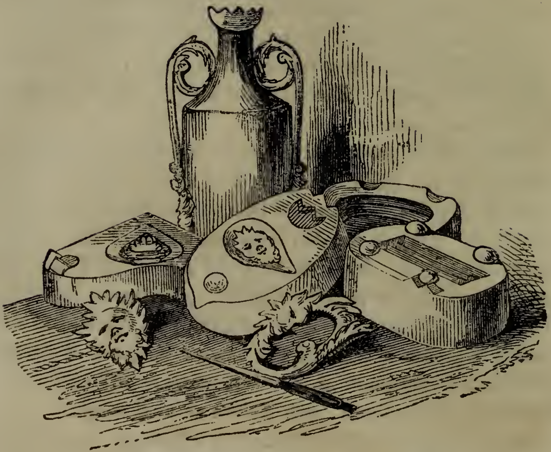
In this department, whatever our Schools of Design, or education, or natural ability could afford, in the development of a knowledge in elegance of form, is important and valuable. The modeller, from drawings made either by himself or by others, has to build up in clay the exact representative of the article to be formed in porcelain. From the handle of a tea-cup up to the most elaborate combination for a piece of drawing-room porcelain furniture, the modeller has to prepare an accurate original in soft clay. Provided with a supply of clay, especially prepared for this kind of work, and with a few simple tools, he elaborates the various parts of his design, whether animals, fruit, flowers, foliage, architectural ornaments, arabesques, or any of the countless varieties of decorative devices; building up his model piecemeal, and carving or cutting out the parts as he proceeds. It has been aptly observed by Mr. Porter, that "the taste of the modeller is put in requisition; calling for the execution on his part of a high degree of skill and ingenuity in forming patterns, and adapting to them appropriate ornaments. To be a perfect modeller, in the higher branches of the art, a man should have an acquaintance with the best productions of the classic climes of Greece and Rome; he should be master of a competent knowledge of the art of design; his fancy glowing with originality, tempered and guided by elegance and propriety of feeling, and restrained by correctness of taste and judgment. To a man thus gifted, the plastic and well-tempered material wherewith he works offers little of difficulty in the execution of his conceptions."

It is only in the costly articles which require *casting* that the model is thus elaborate: when it can be produced by *pressing*, the preparation of the model is generally more simple. The difference between these two modes of manufacture is this: that, in pressing, the shallowness of the mould is such that clay, in its usual plastic state, can be pressed into all the minute devices of the mould; while, in casting, the mould is so deep and elaborate that the clay has to be poured into it in the state of a cream-like liquid. Plates, saucers, oval vessels, lids, spouts, handles, and a large variety of articles which are too irregular to be produced at the potter's wheel and the lathe, and yet not so complex as to require casting, are produced by pressing. But both for pressing and for casting moulds must be made, and these moulds are reversed copies of models produced by the modeller; so that this workman's services are required for all.

Plaster of Paris, prepared in a particular way, is the substance of which the moulds are made. The making of the moulds is quite a distinct occupation from that of modelling, and is carried on in a different part of the factory. A casing of clay is first formed and securely fixed round the model, leaving sufficient space between it and the model for the substance of the mould. The plaster of Paris, being mixed with water to a cream-like liquid, is then poured into the vacant space. In a very short time, in virtue of the well-known qualities of this substance, the plaster solidifies into a compact mass, which is easily separable from the model. The interior of this mould is then found to give a perfect counter-representation of the exterior of the model, in all its minuteness of detail. The model is lastly dried, to prepare it for further use.

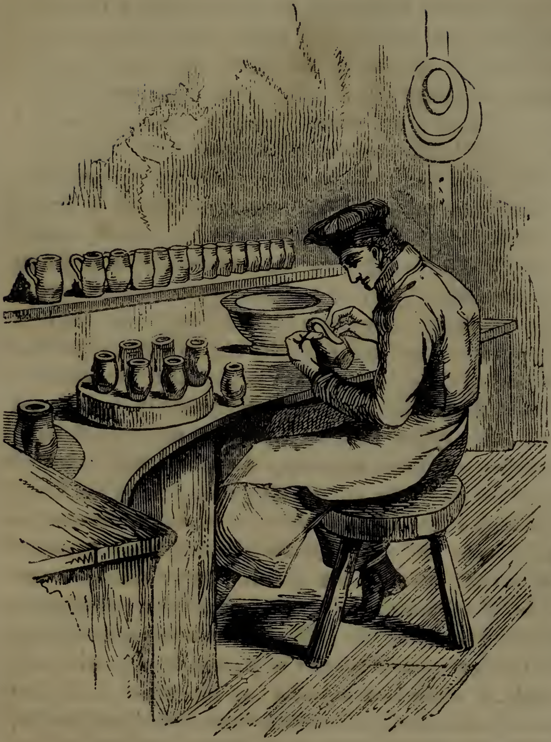
For pressing, the mould is sometimes made in two parts, one half of the figure being on one side, and the other half on the other; the two being made to fit accurately together. Clay is pressed into each half of the mould, and cut off flush, so as to have no superfluity; and the two halves of the mould being brought closely together, each piece of clay receives its impress from the half of the mould in which it lies, and the two pieces are at the same time joined together: so that one piece is produced, presenting a fac-simile of both halves of the mould. This mode is adopted in the preparation of a large diversity or variety of articles. Another arrangement, for the production of plain handles, spouts, &c., is to force clay through an orifice in the bottom of a cylinder, the orifice having that shape which is to be given to the clay. A third arrangement, where one surface of a shallow vessel, such as a saucer or a plate, requires to be moulded, while the other can be formed without a mould, is to lay a flat piece of clay on the mould, press it down with a wet sponge, and give a proper form to the exposed surface by a profile or gauge applied to the wet clay while the latter is revolving. The annexed cut represents a few ornamental articles which required to be produced by pressure, and the moulds used in the pressing.

So varied and numerous are the articles now made of porcelain, that it would be utterly impracticable to classify them all in respect of the mode of manufacture; but it



[Moulds for Porcelain, and Casts.]

will suffice to say that all are produced by one or other of the modes above noticed, viz., throwing at the wheel, aided by profiles or gauges; turning at the lathe; pressing through an orifice in a cylinder; pressing one side on a mould, while the other side is fashioned by a gauge; pressing between two moulds, or the two halves of a mould; and casting while the clay is in a liquid form. In the last-mentioned mode of proceeding, the plaster of the mould quickly absorbs water from the liquid clay which lies in contact with its surface, and brings it to a solid state; and a hardened shell having been thus produced, the subsequent arrangements are such as to make the cast either hollow or solid, according to its form and dimensions.



[Fixing Handles.]

Many a tea-drinker has probably marvelled how the handle of a tea-cup is produced; whether it is fashioned by hand out of the same piece of clay which forms the cup, or cast in a mould with it, or fixed on separately.

The preceding details will have prepared us to understand the real state of the matter,—that the cup, if not too elaborate in form, is 'thrown' at the wheel; that the handle is pressed in a mould, and that the one is afterwards affixed to the other. Handles, spouts, knobs, and small raised ornaments are all attached to the vessels in a similar way, and when the latter are in the 'green state,' between wet and dry. The cement employed is simply a creamy mixture of clay and water, technically termed 'slip,' which is applied to the two surfaces to be joined together, and which enables them to adhere permanently. The clay handle or spout is in such a soft state, that considerable neatness and dexterity are requisite, especially in curving the strip of pressed or moulded clay which is to form the handle—a process represented in the annexed cut. The raised or relief ornaments seen on articles of porcelain are made separately in a mould, and cemented on the vessel by the aid of 'slip,' except when the vessel is of such a kind as to require to be cast or pressed, in which case the ornaments are generally made as part of the pattern itself in the mould. Taper-stands are now made, the construction of which illustrates conveniently the combination of the different modes of manufacture: for the lower saucer or dish is pressed in a mould; the nozzle is made into a 'solid' at the wheel, and then turned at the lathe; the handle is formed in a double mould; and lastly, all these are joined together with 'slip.'

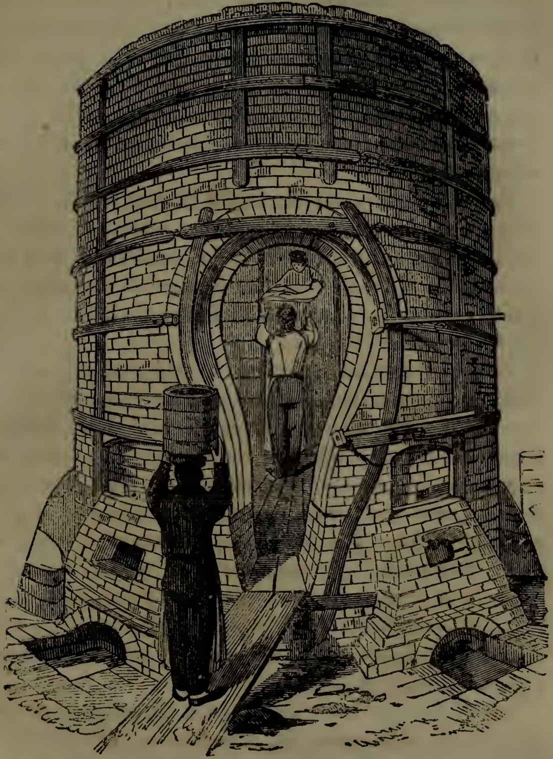
Let us suppose, then, that we have traced all the various kinds of porcelain articles to a finished state in respect of their form and decorations; the tea-pots furnished with handles and spouts, the cups with handles, the jugs with lips, and the more highly decorated articles provided with all which the 'thrower,' the 'turner,' the 'presser,' and the 'caster' can do for them. We shall next be prepared to follow them through the subsequent processes which impart that exquisite appearance so especially belonging to porcelain.

Among the kilns or ovens employed in this manufacture are those called 'biscuit-kilns,' twelve or fourteen feet high, in which the ware is exposed to an intense heat. They are heated by fires ranged round the circumference, each kiln having eight fire-places. The whole interior capacity is fitted for the reception of the articles to be 'fired,' or 'baked.' Very great precautions are necessary in this process; for, if the smoke or flame from the fire attacked the porcelain, it would discolour it at once, and spoil it. To prevent this mischance, all the manufactured articles are put into receptacles called 'seggars,' such as are here represented: these are made principally of a kind of fire-clay capable of resisting an intense heat; and so important are they, that the acquisition of the sort of clay fitted for the purpose has always been deemed a momentous point on the part of the manufacturer. The seggars are of various sizes, shapes, and depths, to suit the different pieces they are to contain. According to the size and shape of the articles, they are either enclosed one in each seggar, or several in each; but in the latter case precautions are taken that they should not adhere together, nor touch each other at more than two or three points: powdered flint is placed at the bottom of the seggars, and pieces of hard fire-clay are so placed within the seggar, that the articles may be supported with as little contact as possible one with another.

The piling of the seggars in the 'biscuit-kiln' is a

[Putting manufactured articles into 'Seggars.']

singular arrangement. The whole interior is filled with them. The top and bottom of each seggar (the former open and the latter closed) being flat, they may be piled one on another, so that each one forms a cover for the



[Placing the 'Seggars' in the 'Biscuit kiln.']

one underneath. As the heat cannot be perfectly equalized throughout the kiln, care is taken that the larger articles shall be exposed to a higher temperature than the smaller.

Thus seggar is laid upon seggar, and pile after pile built up within the kiln, till the whole is filled. Every aperture is then carefully closed—of which the main one is, of course, the door through which the men enter the kiln—and all is ready for the fires to be lighted beneath. The general appearance of the kiln while being filled is here represented.

Forty hours is about the length of time during which they are thus exposed. The precise amount of 'firing' necessary is a delicate point, to be determined only by experience: it must be sufficient to expel all the moisture, and to convert the clay into a kind of semi-vitreous earth, but not beyond this point.

The baked articles are allowed to cool gradually before being drawn from the kiln; and when so drawn they have acquired the state which is called 'biscuit.' Every article shrinks considerably while in the kiln, and the weight is very materially lessened. The biscuit ware has a peculiarly delicate, soft, and white appearance, presenting many points of striking difference compared with its unbaked state. Every article, as taken out of the seggar, is nicely cleaned, to remove all symptoms of flint-dust, &c.; and it is then ready for the process of 'glazing,' by which the dead and unpolished surface of the biscuit is converted into a beautiful glassy surface.

One of the most important steps in the progress of the porcelain manufacture has been the discovery of substances fitted to impart this 'glaze' to porcelain. Any of the substances which will make glass will afford a glaze to pottery; and these substances comprise various alkalies, various oxides of metals, and flint in a variety of forms: but what is the best combination to form a glaze for the more delicate kinds of porcelain is a question which has occupied much attention, not only among manufacturers, but among chemists also. In the commonest kinds of earthenware or pottery the cheapest ingredients are those most resorted to; but in costly porcelain a totally different system is pursued, the excellence of the material being a much more important matter than the smallness of the price. We believe that in this, as in the choice of clays for making the porcelain, each large establishment has a recipe of its own, derived from the experience of the proprietors.

The pieces of 'baked' or 'fired' porcelain being brought into the 'dipping' room, a workman takes them up one by one, holds them in such a manner that there shall be the smallest amount of contact between them and his fingers, and dips them into a trough of glaze. By one of those manipulations which are peculiar to most occupations, he turns the vessel about, on removing it from the glaze, in such a manner that, while every part shall be coated, none shall have any superabundance but what may easily be drained off. The vessels are put down out of his hand, one by one, on a board, which is thence carried to the 'glaze-kiln placing-room.' In this latter room they are piled up in seggars, nearly in the same way as before, but with certain modifications to suit the peculiarity of the circumstances.

The glaze-kilns, like the biscuit-kilns, are each heated by eight fires, and are each filled up with piles of seggars; but in the glaze-kilns the slight opening between the several seggars of each pile is stopped with clay, to prevent more effectually the entrance of smoke and flame into the seggar. The heat for vitrifying the glaze is much less intense than for biscuit-firing, and is continued for a much smaller number of hours. The operation consists in driving off the watery parts of the glaze, and melting the vitreous part, which, in a vitreous state, combines firmly with the biscuit. Where we find, in the cheaper articles of manufacture, the glaze to become discoloured, or the ware discoloured under the glaze, or the glaze intersected by myriads of minute cracks, this always indicates either that a bad choice of ingredients was made or that the management of the glaze-kiln was injudicious; and this is one of the many points in which first-rate porcelain shows its excellence.

We have now brought the porcelain to what might be deemed a finished state, so far as regards the actual service demanded from it: but it is very rarely that such porcelain as we are now considering leaves the hands of the manufacturer in this state; it is nearly always decorated either with painting or gilding, or both, before it passes into the hands of the customer. We follow it therefore to the 'painting-room,' where artists, seated before a range of windows, apply, with a camel-hair pencil, mineral and oil colours to the surface of the porcelain.

In China this branch of manufacture is so subdivided, that one man paints blue, another red, another yellow, &c., so that each article goes through a great number of hands during the process of painting. But in England the subdivision is more rational. One man takes flowers, another foliage, a third animals, a fourth landscape, a fifth figures, a sixth heraldic bearings, and so forth; confining themselves mainly to that which their taste and studies have enabled them to effect artistically. Each painter holds the piece of porcelain against a projecting part of his table, so as to retain it firmly; or else, if a circular ornament is to go round it, he rests it on a support which may enable it to rotate with facility. The colours employed in this process are chiefly oxides of various metals, worked up to a liquid state with spirits of tar and of turpentine, and amber oil. Those ornaments which are subsequently to present the brilliant golden appearance so familiar to us on the better kinds of porcelain, are effected by a preparation of refined gold mixed up with some of the liquids just mentioned into a dark brown colour, which has no semblance to a golden hue until after it has been burned in a kiln.

Some of the articles of porcelain have a white or unpainted ground, decorated with coloured ornaments; while others are painted over the whole surface with a ground-colour, the laying on of which is the work of a particular set of painters, who show great art in the uniform tinting produced. Not only are vessels for table-service thus painted, but the side-slabs for fire-places and a large variety of decorative furniture are now made in porcelain, and then subjected to the taste and skill of the painter. This is one of the branches of the porcelain manufacture in which the English have made very rapid progress within the last few years.

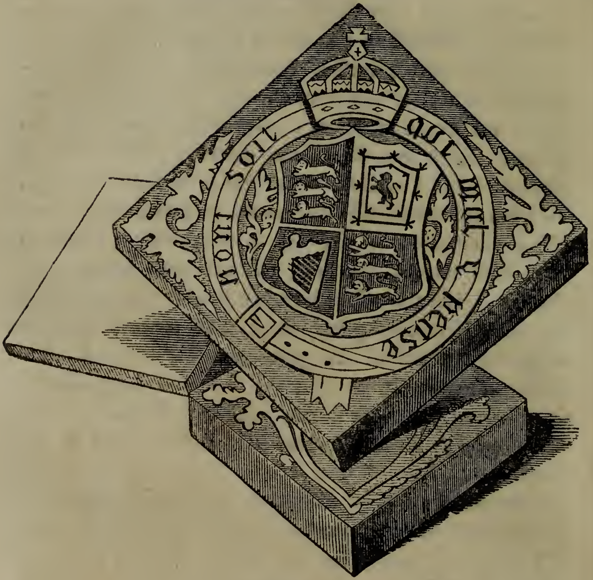
Conveniently placed with respect to the painting-room are the 'enamel-kilns,' in which the painted articles are exposed to a heat sufficient to make the colours adhere to the porcelain. These kilns are a kind of arched oven, having a door at one end, and gratings within on which the articles are placed. The most scrupulous care and delicacy are displayed in managing these kilns, as to the temperature and length of exposure. Sometimes the painter requires to partially heat the porcelain two or three times during the process of painting, to ascertain the effect of his colours, and to combine them well with the porcelain. Indeed the care required in this process is very little less than in the exquisite one of enamel-painting.

We next follow the costly results of all the preceding labours to the 'burnishing-room,' a large apartment occupied by women and girls employed in burnishing those parts which have been gilt in the painting-room. The burnishers are formed of blood-stone and agate, brought to a very smooth surface, and variously shaped to adapt them to the curvatures of the porcelain. Each workwoman is seated at a bench with her face towards a window, holding the porcelain in the left hand, and the burnisher in her right, with which she rubs the gilded parts until they are brought to a brilliant gloss.

Tessellated Tiles.—We must here say a few words respecting a branch of manufacture which promises to be much extended in England, viz., *tessellated tiles* for pavements, &c. Whoever has seen the Temple Church since it has been renovated, will have noticed the beautiful pavement which it displays, formed of a vast number of rectangular tiles about six inches square, glazed on the upper surface.

The tessellated tiles are formed of two differently coloured clays, one imbedded in the other, and disposed so as to form an ornamental device. The tile is first made in clay of one colour, with a depression afterwards to be filled with clay of the other colour, and this depression is formed by the aid of a mould. In the first place, the modeller models in stiff clay an exact representative of one of the tiles, about an inch thick, cutting out to the depth of about a quarter of an inch the depression which constitutes the device. When this is properly dried, a mould is made from it in plaster of Paris, and from this mould all the tiles are produced one by one. The ground-colour of the tile is frequently a brownish clay, with a yellow device; but this may be varied at pleasure. Let the colour be what it may, however, the first clay is mixed up very thick, and pressed into the mould by the aid of the press seen in the cut. On leaving the press it presents the form of a damp, heavy, uni-coloured square tile of clay, with an ornamental device formed by a depression below the common level of the surface.

The second coloured clay, so far from being made stiff like the first, has a consistence somewhat resembling that of honey; and herein lies one of the niceties of manufacture, for it is necessary to choose clays which will contract equally in baking, although of different consistence when used. The tile being laid on a bench, the workman plasters the honey-like clay on it, until he has completely filled the depressed device, using a kind of knife or trowel in this process. The tile, in this state, is then allowed to dry very gradually for the long period of eight weeks, to accommodate the shrinking of the clays to their peculiar natures. After this, each tile is scraped on the surface with an edge-tool, till the superfluous portion of the second clay is removed, and the two clays become


honi soit qui mal y pense

[Tessellated Tiles.]

properly visible, one forming the ground and the other the device. In this state the tiles are put into a 'biscuit-kiln,' where they are baked in a manner nearly resembling the baking of porcelain, but with especial reference, as to time and temperature, to the quality of the clays. From the biscuit-kiln they are transferred to the 'dipping-room,' where they are coated on the upper surface with liquid glaze by means of a brush. Lastly, an exposure to the heat of the 'glaze-kiln' for a period of twenty-four or

[Making the Tiles.]

thirty hours causes the glaze to combine with the clay, and the tiles are then finished.

Earthenware.—Let us now transfer our attention from the porcelain to the pottery and earthenware manufacture, associated especially with the Staffordshire district.

The district known as the Staffordshire Potteries is a portion of the country about ten miles in length and two or three in breadth, lying a little eastward of the town of Newcastle-under-Lyme, and occupying an area of perhaps twenty thousand acres. It may be characterised as one long street from end to end, for the successive towns and villages are so near each other, and have gradually been so connected by rows of houses, that the eye glances from one to another with scarcely an appreciable interruption. The towns, townships, hamlets, and villages are very numerous; but the most notable are Tunstall, Burslem, Cobridge, Hanley, Shelton, Etruria, Stoke, Fenton, and Lane End; and if we pass through these towns on the high road, we shall find on either side a continued string of potteries and porcelain-works, so large and so numerous that one may almost wonder where a market can be found for the immense mass of articles produced there.

This, then, is the Pottery district; and on inquiring into its history, we shall find that the busy hive of potters has been accumulated there by two circumstances—the existence in the neighbourhood of mineral products indispensable to the manufacture; and the facilities which are always afforded when many men of one trade congregate in one place. The talents and energies of a Wedgwood would have created a manufacture anywhere; but when these were brought to bear in a district already distinguished for its manufactures, the spot could not fail to become a great centre of productive industry.

There are indications that the pottery art was exercised in Staffordshire in the time of the Romans; for many specimens of earthen vessels are occasionally dug up in the district, referable to no later period of English history. Whether, or to what extent, the manufacture was there carried on in the ages subsequent to the Roman occupation, can now hardly be answered. It will suffice to say that Burslem, the "Mother of the Potteries," exhibits proof that this manufacture has been carried on there for centuries. Before the time when Dr. Plot made his survey of Staffordshire in 1686, there were here and there kilns and ovens, with rude buildings covered with thatch. The manufacture of *butter-pots* seems to have been in the seventeenth century a kind of staple product at Burslem. Plot says that "the greatest pottery they have in this county is carried on at Burslem, near Newcastle-under-Lyme, where for making their several sorts of pots they have as many different sorts of clay, which they dig round about the town, all within half a mile distance, the best being found nearest the coal, and are distinguished by their colours and uses." He also tells us that at that time (1686) "the factors buy their butter by the pot, of a long cylindrical form, made at Burslem, of a certain size, so as not to weigh above six pounds at most, and to contain at least fourteen pounds of butter."

The wares made at that time at Burslem (then the only pottery-town in the district) were of a very rough and coarse kind; but a discovery made towards the end of the seventeenth century paved the way for great improvements: this was the use of salt in glazing pottery, apparently until then unused in this country. The incident is recorded thus:—At Stanley Farm, situated not far from Burslem, the servant of Mr. Joseph Yates was boiling in an earthen vessel a strong lixivium of common salt, to be used in curing pork. During her temporary absence the liquor boiled over, and some ran down the sides of the vessel, covering the surface with a liquid which on cooling appeared as a glaze. Mr. Palmer, a potter of the neighbourhood, being made acquainted with the fact, speedily availed himself of it, and established the manufacture of the common brown glazed ware. There were salt-beds in some of the neighbouring districts, and this led to the extension of the manufacture to spots still farther from Burslem.

About the year 1690 a very remarkable instance of the extension of the potteries near Burslem occurred. At that time the East India Company were in the habit of importing from the East "unglazed red porcelain" vessels, of a beautiful red colour and form, which had never been equalled in England on account of the want of the proper clay. It was discovered, however, that at Bradwell and Brownhills, near Burslem, a fine-grained and beautifully-tinted red clay could be procured; and this, together with an abundant supply of coals for the ovens, led to the establishment of a pottery at Bradwell by the Messrs. Elers, from Nuremberg. Here they made red porcelain unglazed tea-pots, simply of the fine red clay of the district; as also black or Egyptian porcelain, by adding manganese to deepen the tint. The brothers Elers seem to have been in advance of their neighbours, and to have taken extraordinary precautions to baffle curiosity. The servants employed were ignorant and stupid; and the thrower's wheel was turned by an idiot: each person was locked in the place where he was employed; and such were the precautions to preserve the supposed secret, that previous to the workpeople retiring at night, each was subjected to a rigid examination. However, all their precautions were fruitless; for two persons, named Twyford and Astbury, succeeded in worming out the secret. The former got employment at the works; and by manifesting entire carelessness and indifference to the nature of the processes, he masked his real object, which was to find out all that was new in the operations at Elers' works. Of the other man, Astbury, the account handed down is very remarkable. Having assumed the garb and appearance of an idiot, with all proper vacuity of countenance, he obtained employment at the Bradwell manufactory, and received the cuffs, kicks, and jeers of his fellow-workmen in a manner accordant with his assumed character. He was put from one occupation to another, having apparently just sense enough to make him worth the pittance which he received. Meanwhile he lost no opportunity of observing the processes and working apparatus; and on returning home each evening he formed models of the several kinds of implements, and made memoranda of the processes. He continued this practice for nearly two years, until he ascertained that no further information was likely to be obtained, when he availed himself of a fit of sickness to continue at home; and this was represented as very malignant, as a means to prevent any person visiting him. After his recovery, the Elers seemed to have a suspicion that he was too clever for them, and he was discharged: but they soon found that he had taken their secret with him; and they had the mortification to see the Burslem potters avail themselves of methods which they thought rested with themselves.

Such is the tradition. Those who have read much on the history of manufactures will call to mind many parallel instances in which men have feigned illness or stupidity as a means of discovering processes otherwise kept secret. There may be a little colour of romance thrown over the story; but there is no reason to doubt the main points.

Thus step by step did the manufacture spread, the establishments increasing in number as new kinds of ware became introduced. Topographically considered, this extension travelled southward; for Burslem, the parent pottery-town, is nearly at the northern extremity of the district. Twyford and Astbury commenced manufactories at Shelton, about three or four miles from Burslem, and there carried on the red porcelain work, and the white ware glazed with salt. Some years afterwards, Mr. Astbury's name became connected with another singular adventure, by which another step was made in the progress of the manufacture. While on a journey to London, on horseback, Astbury was compelled to seek a remedy for the eyes of his horse, which seemed to be rapidly going blind. The ostler of an inn near Dunstable burned a flint-stone till quite white, pulverized it, and blew a little of the dust into the eyes of the horse, by which they were made to discharge copiously. Astbury, having noticed the white colour of the calcined flint, the ease with which it was then reduced to powder, and its clayey nature when discharged in the moisture from the horse's eyes, immediately conjectured that it might be usefully employed to render of a different colour the pottery he made. On his return home he availed himself of his observation, and soon obtained a kind of ware exhibiting marked improvement on the pre-existing kinds. Mr. Porter remarks, that "it could have been no common mind which led Astbury to the long-continued pursuit of his object by means so humiliating; and which also enabled him, on the occasion just related, to seize upon a fact thus accidentally presented, and which, although of high importance to his art, might have passed unheeded before the eyes of many a common-place manufacturer."

We next come to the era of Mr. Josiah Wedgwood, who was to the pottery manufacture what Watt was to the steam-engine and Arkwright to cotton-spinning—its greatest improver. The pottery district of Staffordshire owes to this remarkable man a large measure of its wealth and of its commercial importance. We find various items in the history of the potteries during the early half of the last century, in which the names of Mr. Aaron Wedgwood, Mr. Thomas Wedgwood, and Mr. John Wedgwood are mentioned: these were potters, apparently in rather humble circumstances, in and near Burslem. Thomas was said to have been an excellent 'thrower' at the wheel, while John was a skilful 'fireman' in the glazing department; and both left their father, Aaron Wedgwood, to set up for themselves in Burslem. It was about a century ago when the two brothers established themselves; and they soon created a large business by the industry and sagacity with which they sought out the most improved clays and glazes for their wares.

Josiah Wedgwood, the most distinguished of the family, was the son of Thomas, and was born in Burslem, in 1730. His early education was very limited; and at the age of eleven he worked for his father as a 'thrower.' An old man, many years afterwards, used to relate that he had been engaged by Thomas Wedgwood to make 'balls' (as the lumps of clay are called) for the two sons, Josiah and Richard, which they, as throwers, formed into vessels, the two youths being seated in the two corners of a small room. Some years afterwards Josiah Wedgwood joined in partnership with one Harrison of Newcastle, and afterwards with a Mr. Whieldon; but he appears to have returned to Burslem about 1760, and to have there set up in business on his own individual resources. He established two manufactories at Burslem, where he made knife-handles, green tiles, imitative tortoiseshell and marble plates, white stone-pottery, and other articles. He next turned his attention to 'cream-coloured' ware, for which he had soon such a demand that he built a third factory. After a time Wedgwood opened a warehouse in London, for the management of commercial dealings, and as a depôt for articles contributory to that remarkable style of manufacture which he soon struck out. He collected vases, busts, cameos, intaglios, medallions, seals, and other works of art; and began to exercise his ingenuity in imitating them in pottery or porcelain. His imitations of Greek, Roman, and modern Italian productions were so exquisite that he gained renown throughout Europe; and men of taste were accustomed to visit Burslem to see the operations of his establishment. The Barberini or Portland vase will always be closely connected with the name of Wedgwood, as showing what the potter's art can effect. This celebrated vase being put up to auction, Wedgwood was very desirous of buying it as a pattern from whence to manufacture copies. The Duchess of Portland 'bid' for it; but Wedgwood bid against her so pertinaciously, that it attracted the Duke's attention; who, when he knew the cause of Wedgwood's solicitude, offered him the loan of the vase for an indefinite period, if it would terminate his biddings. He did so; and the vase was sold to the Duchess for nearly two thousand guineas. Such is the account given by Mr. Shaw. Wedgwood thereupon employed the finest modellers and the most talented workmen in every branch, through whose aid he produced fifty copies of the vase, which he sold for fifty guineas each: as a commercial speculation it failed, but it raised his name to a high pitch of eminence as a tasteful manufacturer.

Meanwhile he did not neglect the more useful varieties of earthenware. He presented to Queen Charlotte some specimens of painted cream-coloured ware; which so pleased the Queen, that she ordered a complete table-service of the same kind: the pattern selected was thereafter known as the 'Queen's pattern,' and the ware as the 'Queen's ware,' while Wedgwood himself received the appointment of 'Potter to the Queen.' He next invented a much-admired ware known as Jasper-ware: this was a beautiful white ware, capable of receiving rich and pure colours on any part of its surface, by which striking imitations could be produced of various kinds of ancient works of art. A kind of black ware, called Black Egyptian, was also by him applied to the making of busts and figures.

By the year 1777 a canal, the 'Grand Trunk,' had been opened for the conveyance of the pottery from the Staffordshire district to the two great northern ports of the kingdom, Liverpool and Hull. But at the time Wedgwood commenced his labours the means of conveyance were miserably insufficient. In some instances the flint used in the manufacture was carried from the mill where it was ground to the manufactories by men; in other instances, by horses, which carried tubs, holding two pecks each. The chapmen, or dealers, kept gangs of horses which carried small crates; and in these crates was stowed the ware, to be carried from place to place, and exhibited to purchasers. Afterwards, when the roads became improved under the provisions of an act of parliament, carts and waggons were substituted for pack-horses; and persons travelled from place to place for orders, instead of the goods being hawked about for sale. At length the Grand Trunk Canal was boldly projected by Brindley; Wedgwood advocated it earnestly, and, as it is said, turned up the first clod of earth with his own hands, near his works at Burslem.

When the canal opened a communication between the potteries and various parts of England, Wedgwood removed from Burslem, and built a large manufactory on the banks of the canal; near which he also built an elegant house for himself, and a village of neat dwellings for his workpeople; calling the whole *Etruria*, after the ancient Italian state which produced such beautiful specimens of earthen vases, &c. Here Mr. Wedgwood continued to reside till his death; and here his descendants still carry on the business which he founded. This handing down of manufacturing establishments from father to son has been very observable in the potteries.

Beyond this point we need not trace the history of the Potteries. The celebrity of Wedgwood and the exertions of other manufacturers, together with the gradual introduction of printed ware, porcelain, &c., raised the Potteries to a commercial rank which they have ever since maintained.

Let us see, then, what kind of a district this is, which has, *par excellence*, acquired the name of "The Potteries;" a name so distinctive, that when the parliamentary boroughs were remodelled in 1832, the franchise was given to the whole of this district as one borough, since which time there has been an "honourable member for the Potteries," although, nominally, the borough is designated by one of its towns, Stoke. Supposing a visitor to approach the Potteries by the Grand Junction Railway, and to pass through Newcastle-under-Lyme towards Stoke, he will arrive at the district about midway between its two extremities: Tunstall, Burslem, Cobridge, Hanley, and Shelton will be to the north; Fenton, Lane Delph, Lane End, and Longton will be southward; and to whichever direction he may turn, he will not be slow in observing that the towns consist mainly of small houses, in streets branching out from the high road, which runs nearly north and south. There are not many handsome buildings, and still fewer monuments of antiquity; but, on the other hand, there are very few indications of squalor and wretchedness. Nearly every person throughout the district lives directly or indirectly by the manufacture of pottery; and as this branch of manufacture is subject to less fluctuation than most others in the north, the instances of extreme poverty are rare. There is no living in cellars and hovels; nor is there any congregating of twenty or thirty families in one house, as some of our large towns exhibit: the houses are small and humble, it is true, but they exhibit indications of comfort which show that a large amount of wages must be distributed weekly among the seventy thousand inhabitants of the district.

Pottery is not a domestic manufacture; that is, it is not carried on in the houses of the workmen or in small shops; it is conducted in large manufactories; so that the three features which the district mainly exhibits are —the manufactories themselves, the private dwellings of the proprietors, and the streets of small houses inhabited by the workpeople. The manufactories are distinguishable by large, lofty, dark-coloured structures, shaped somewhat midway between a sugar-loaf and a bee-hive; these are the ovens in which the ware is baked; or rather they are 'hovels,' which surround the ovens, and within which the men stand to attend to the ovens. Every establishment has these 'hovels,' and the extent of the operations is in some degree indicated by the number of them. Frequently, in walking along the high road, we may see a handsome private dwelling, with 'hovels' and other buildings behind it; in such case the probability is that the house is inhabited by the proprietor of the works. If a stranger ask a question concerning these manufacturing premises, he will be told that it is "Mr. So-and-so's bank"—the pottery-works being known technically as 'banks'—why, we cannot say. "Whose premises are those yonder?" "That's Mr. Wedg'ood's bank at Trury," was the reply; for Etruria is stripped both of its beginning and its end by the workpeople.

The village just named, Etruria, is situated a little out of the main road through the potteries. It is in the road from Newcastle to Hanley, and consists almost entirely of one street, containing about a hundred and fifty houses; these were built by Mr. Josiah Wedgwood, and are occupied chiefly by persons employed in the neighbouring works. A singular uniformity is exhibited by these dwellings, both in their outward appearance and their interior arrangements. The street-door opens directly into the front parlour; in fine weather the door is always open, and, in almost every case, the first object which meets the eye of a passer-by in each house is a chest of drawers, immediately opposite the door. Now, without discussing the question how far a chest of drawers is a test of respectability, it is always observable that many comforts are collected around a family which possesses this article of furniture: it shows that there are "Sunday clothes" to be taken care of, and a decent pride in their preservation. The windows too, one and all, are decked with flowers, planted in pots which would put to shame the coarse red flowerpots of a London window-sill.

There is one external mark by which the pottery operatives are to be known, all the way from Tunstall to Lane End—in the 'banks,' on the road, and at the doors of their own houses. This is the small, drab felt, close-fitting, hemispherical skull-cap, which is worn by most of the men and boys. The manufacture of these caps is largely carried on at the neighbouring town of Newcastle; and they are worn because they are cheap, and because, as it is asserted, they "keep the head warm in winter and cool in summer."

At all the various towns, there are 'banks,' or pottery manufactories, on a very large scale, as well as others of a smaller size. In some of these establishments the very finest kinds of porcelain are manufactured; in others only the common earthenware; while others again combine both classes of productions. At Lane End, besides a few establishments of the higher class, there is a very large number of minor 'banks,' where the commonest kinds of stone and yellow ware are produced, and whence the hawkers and street-dealers all over England obtain their supply. Near here too, as well as in many other parts of the Pottery district, there are coal-pits, from which is procured, for six or eight shillings per ton, an abundant supply of coal well fitted for the pottery ovens, although not equal to the South Staffordshire coal for open fires. At a little village near Tunstall all the cottagers seem to have their "coal-cellars" in the open air; for the coals are thrown down in the front of each house by the side of the door, and thence carried in as wanted.

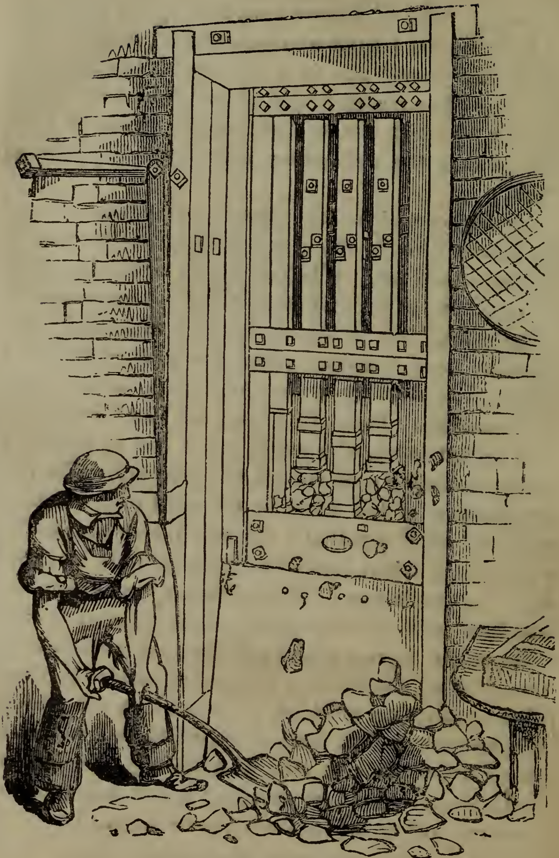
The structures which can correctly be termed "public buildings" are but few in the Potteries. Churches, chapels, market-houses, and town-halls are the principal. In a small street in Shelton there is a neat building appropriated as a "Pottery Mechanics' Institution." It was established by a few noblemen and some of the chief potters of the district some years ago, and has a small lecture-room, a library, and class-rooms for various branches of instruction.

Such are a few of the external characteristics of the district. Let us next witness the internal. In some of the larger of these 'banks' (employing nearly a thousand men each) there are numerous groups of buildings called 'squares,' designated according to the purpose to which they are applied. One, for instance, is the 'dish-makers' square;' that is an open area surrounded by buildings, in which the makers of dishes work. Then there are the 'plate-square,' the 'saucer-square,' the 'coloured-body square,' the 'printer's-square,' &c., each comprising a court or area encircled by buildings. One, too, called the 'black bank,' affords an illustration of the nomenclature spoken of before; this being a 'bank,' or series of workshops, where black ware is made. Besides these are the numerous biscuit-ovens, glaze-kilns, annealing-ovens, &c. Most of the large works are contiguous to the Grand Junction Canal, and exhibit a large area, occupied with the crude material for manufacture; such as the *chert*, for the floor of the grinding-mills; the *gypsum*, or *sulphate of lime*, to make plaster moulds for casting; the *flints* from Gravesend and Northfleet, as one material for pottery; the Staffordshire *marl*, for forming the seggars, or fire-cases; the Devon, and Dorset, and Cornwall *clays* and *stones*, employed in the manufacture; and the *coals* with which the ovens and kilns are to be heated. It is a curious circumstance that at the present day the Staffordshire clay is not employed for any of the pottery: it has been entirely superseded by the clays of other districts, and is now only used to make the seggars: it is a kind of marl found interstratified with the coal, and is easily procured.

We now proceed to such parts of the manufacturing details as have not been described in the earlier parts of this chapter, and relate to earthenware rather than porcelain. Flint and a few kinds of clay form the main ingredients of all the numerous varieties of pottery and porcelain, and are made fit for the potter's use by nearly the following processes:—The flints, brought from Gravesend in irregularly shaped pieces, are placed in a kiln, shaped somewhat like a lime-kiln, where they are stratified with layers of small-coal. Heat is applied, and the flints are burned or calcined to a white colour, in which state they are more easily broken than before. These pieces are then pounded to still smaller fragments by the 'stampers' represented in the next cut, and which act in a curious manner. These stampers are perpendicular pieces of wood loaded with iron, and fall upon or into a box, whose bottom consists of a strong iron grating: they are raised alternately by machinery connected with a steam-engine, and made to fall heavily upon the pieces of calcined flint, which become thereby broken small enough to fall through the iron grating. The flinty fragments are then ground to a perfectly fine state in a large vat or vessel designated the 'mill.' It is a circular vessel, twelve or fourteen feet in diameter, having four arms extending from its centre, which arms carry round what, in another form of the machine, would be the upper millstone. The bottom is lined or paved with Welsh 'chert,' a species of flint; and the arms carry round large heavy blocks of the same substance, by which the calcined and crushed flint, after being thrown into the vessel and covered with water, is found to be a consistence nearly as fine as cream.

The Cornish clay is partially prepared in Cornwall from a kind of decomposed granite, called Cornish stone, which is ground and washed, and the lighter argillaceous particles allowed to flow into channels and pits, where a sediment forms, which is afterwards made into cakes, and then barrelled for shipment to Liverpool. The Dorset clay receives hardly any preparation before it arrives at the Potteries. The sulphate of lime, from which the plaster of Paris for the moulds is to be produced, is first broken small, then ground fine in a mill similar to a flour-mill, and placed in a trough formed of fire-brick: heat is then applied, by which the sulphate loses its crystalline form, and assumes the well-known appearance of plaster of Paris.

All these operations are preparatory to the 'slip-making,' the process whereby the clay is brought into the state fit for the potter's use. Whether clay be for the finer kinds of porcelain or for earthenware, the arrangements for 'slip-making' are analogous in their character. The materials travel downwards, from one level or stage to a lower one, and then to a lower one again, in the course of preparation. Each kind of clay and flint is beaten up, in a distinct vessel, with water, into a sort of cream, by means of rotating arms worked by machinery. The proper thickness of this cream is estimated by the number of ounces which a pint of it will weigh, each kind having a recognised weight known by experience to be best fitted for the object in view. These different creams then flow into large tanks, and from thence along troughs into other tanks, where they are mixed together; gauge-marks being used to afford a guide as to the quantities mixed together. Taps or valves are provided, through which the mixture falls into very fine silk lawn sieves, which have a reciprocating motion given to them by machinery: the fineness of this lawn (for the best porcelain) is such that there are three hundred threads to the square inch; and the cream thereby becomes reduced to an extremely fine state by the time it has passed through the sieves.



[Flint-crushing.]

[Pottery-turning.]

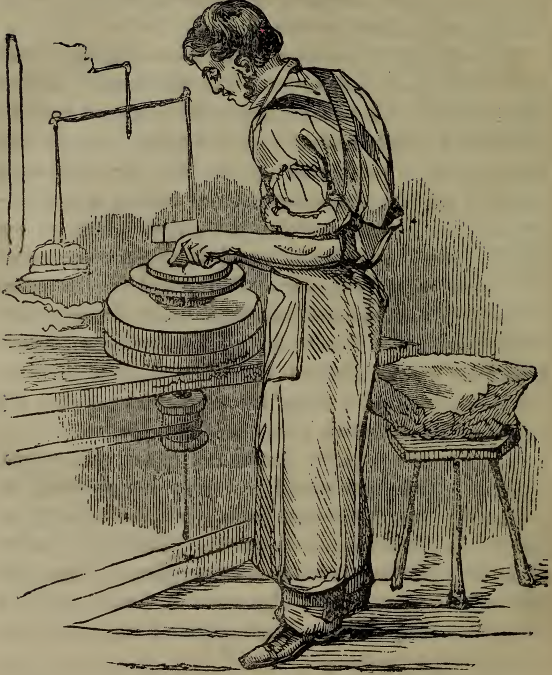
This mixture, then, is called 'slip,' and we follow this slip to the 'slip-kiln,' a remarkable and very long building. This place consists of a low room, having on either side shallow slip-kilns and a passage down the middle. The kilns are merely open troughs, sometimes fifty or sixty feet long, formed of fire-brick, and heated with flues underneath. Here the 'slip,' or clay-cream, remains exposed to heat for twenty-four hours, by which it evaporates to the stiffness of clay.

One more process is necessary before the clay is ready for the potter. When taken from the slip-kiln it is not sufficiently smooth and homogeneous, but requires a kind of annealing or kneading. This used, in the early history of the manufacture, to be performed by laborious manual operation; but a very ingenious and effective kind of apparatus is now employed for this purpose. It consists of an inverted conical machine, down the centre of which runs an axis provided with knives or cutters. The clay, being put into this machine, is cut and pressed so as to become thoroughly amalgamated, and finally forced through an aperture in the bottom of the machine.

The clay, being thus prepared, is transferred to the 'plate-maker's square,' the 'dish-maker's square,' the 'throwing-room,' or to any of the numerous workshops where the potters are employed. How the general process of 'throwing' is effected, by which the greater number of earthenware vessels are made, we have already given a description, and also of the mode in which the 'handle-maker' proceeds. We may therefore pass over these operations here, and notice one or two others. The 'turner,' it will be seen from the preceding cut, works at a lathe in a manner very similar to the turner in wood: the 'thrown' and partially-dried vessel is fixed to the chuck of the lathe, and by means of iron and steel tools of various shapes, the turner gives symmetry of form and smoothness of surface to the vessel.

Plate-making, dish-making, and saucer-making, constitute very large departments of the manufacture, and in such works as are now engaging our attention each department is wholly distinct from the others. One of the plate-makers is represented in the next cut, which will illustrate the following description of making a plate :—Beneath the workman's hands is a vertical pillar, on the top of which is a horizontal wheel bearing a reverse copy of a plate made in plaster of Paris; that is, the upper surface is the same size and shape as the inside or face of the plate which is to be made. The workman, having beaten out a piece of clay to nearly the required thickness and diameter, lays it upon the plate-mould, places this mould on the horizontal wheel, and bids his attendant (a lad) set it into rotatory motion by means of a winch-handle. While the mould and clay are rotating, he presses the latter down upon the former with a wet sponge, and then proceeds to give the contour to the upper surface of the clay (to form the *bottom* of the plate) by means of gauges, ribs, or profiles. The plate is thus formed in a very short time; the plaster mould giving the one surface and the gauge the other.

Dishes, saucers, and all flat vessels of which one side is scarcely seen, are made in a similar manner, the least important side, generally the bottom, being formed by means of the gauges or patterns, while the surface which is to be visible is shaped by means of the plaster-mould. The plates, &c., are not removed from their respective moulds directly they are made; they are put into drying-stoves, mould and all; then taken out and trimmed smooth



[Plate-making.]

by passing the profile-gauges again over them; again stoved, and then separated by the contraction of the clay. But when both surfaces of a flat vessel, such as in the more ornamental kinds of porcelain, are to be visible, the vessel is generally moulded on both sides by a more complicated process.

How the ware is brought from the 'green' state to the 'biscuit' state, was sufficiently explained in the earlier part of the chapter, and renders any detailed description unnecessary here. The manufactured vessels, whether thrown at the wheel, or pressed, or cast in moulds—whether of earthenware or of porcelain—are placed in seggars, or fire-cases, as a means of protection from smoke, and these seggars are placed in the biscuit-ovens which are so numerous at these works.

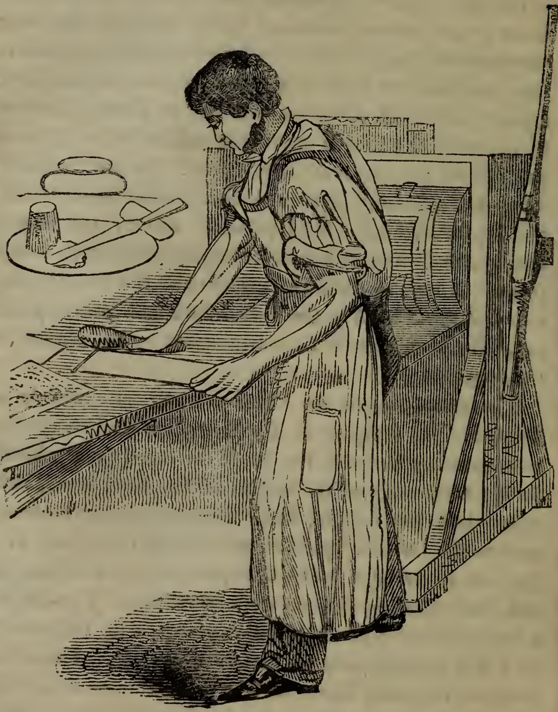
The 'biscuit-warehouse,' in which all the ware is temporarily deposited after being 'fired' in the ovens, is very striking to a stranger, from its large size, and the enormous piles of ware always lying there. In one factory we have seen as many as four thousand dozens of common white basins, all of one size, and all piled in one pyramidal heap in the biscuit-warehouse!

The manner in which earthenware is commonly decorated is strikingly different from that adopted with respect to porcelain. The decorations on porcelain, as have been pretty fully explained, are produced by painting, with camel-hair pencils, various devices on the porcelain, the paint or pigment being formed of mineral colours, which are afterwards made to adhere permanently to the porcelain by the heat of the annealing-kiln. In pottery, however, a cheaper and more expeditious mode is adopted. One kind is called gold or silver *lustre-ware*. To produce the metallic lustre on the surface of this ware, certain metallic oxides are mixed up with essential oils to the consistence of a paint, and then applied with a brush over the surface of the vessel: the heat of a kiln afterwards dissipates some of the component ingredients, and leaves the metallic lustre visible; but the metals employed are merely substitutes for gold and silver, not the costly metals themselves.

Another variety, called 'dipped-ware,' receives its decorations in a manner so remarkable as to form one of the most curious operations of a pottery. It is a cheap kind of ware which is thus ornamented, and may be known by the fanciful but rather indefinite devices on the surface, in three or four different colours; the device being raised somewhat above the general level of the surface, but similar to it in texture. After the vessel has been turned it is fixed to a wheel, which is made to rotate while the workman effects the operation. We will suppose that the vessel is to have a device in three colours, brown, yellow, and blue: in such case the workman prepares three kinds of clay, coloured to the proper tint, and brought to the consistence of paste or cream by admixture with water. A portion of these three he puts into a kind of funnel having three compartments, so that all three remain separate, and yet flow out of three adjoining apertures at the bottom simultaneously. This funnel the workman holds over the vessel while revolving, in such a manner that a little stream of tri-coloured paint shall drop upon it, and form bands, stripes, spots, curves, or spirals, according to the manner in which the funnel is held and the velocity with which the vessel rotates. The three colours are contiguous, and flow in a united stream from the funnel; yet they are perfectly distinct in their position in the vessel. The vessel, it will be understood, is on its side, and rotating on a horizontal axis. The quickness with which this process is effected is quite astonishing, and the whole affair demands singular dexterity in the workman.

Perhaps in the whole range of the pottery manufacture, there is no kind of decorative operation which has been more generally approved, or which has tended more to give neatness to the appearance of the manufactured articles, than that of 'blue-printing,' or the transference to the ware of a device previously printed on a piece of paper from an engraved copperplate. Before the introduction of this kind of ware there were two kinds, called 'blue-painted' and 'black-printed' wares: the former having merely a small border or edging round each vessel, painted in blue colour with a pencil; and the latter having a device transferred to the glazed ware by a kind of printing. But both were in time superseded by the method of 'blue-printing.'

The arrangements for 'blue-printing' are simply as follow:—The designer in the first place draws a design, corresponding in size to the size of the vessel to be printed. In the early stage of the system no fine lines were introduced into the design; but coarse unmeaning patterns, such as the 'willow' pattern, were alone employed. By degrees, however, a better taste prevailed, and landscapes and other pleasing subjects were introduced. The design, when finished, is given to an engraver, who engraves it on a flat copper-plate in the usual manner. From the plate so engraved impressions are taken upon a peculiar kind of thin paper, made expressly for this purpose. The colour for the impression is a mixture of certain metallic oxides with oil, and is brought to the thickness of a cream. The engraved plate is placed upon a flat stove; and, when heated, the printer rubs the ink well into the device, as seen in the next cut. With a knife he then scrapes off the superfluous ink from the surface, and rubs the



[Printing Blue-ware.]

plate quite clean, leaving ink only in the engraved device. Meanwhile the paper has been moistened in soap and water; and an impression is then taken by means of a small roller-press.

Immediately that the printed paper is ready, it is handed to a woman called a 'transferrer,' who, in the manner next sketched, lays it down upon the plate or other earthenware vessel which is to be printed. Sometimes it can be put on in one piece; while at other times it is cut into a few pieces by another female, and then adapted to the various curvatures of the vessel. The transferrer next takes a kind of rubber, formed of a roll of flannel wrapped round the end of a stick, and rubs the paper very forcibly down upon the vessel, the coloured surface being next to the vessel; this rubbing is so violent, that if the paper were not of a tough quality (though thin) it would be worn into holes. The ware, being in the porous 'biscuit' or unglazed state, imbibes the colour from the paper. The vessel is immediately handed to another female, who immerses it in cold water, and washes off all the paper from the surface. It is then seen that the ware has imbibed the colour so intimately that the washing away of the paper has not removed it from the ware: the device is perfectly transferred. The ware is placed in a kiln, to drive off the oil from the ink; and the printed vessel is then ready for the process of glazing. Thus is effected the decoration of a kind of ware, the introduction of which, to use the words of Mr. Porter ('Treatise on Porcelain'), "has added materially to the decent comforts of the middle classes in England, and has more than any other circumstance contributed to the great extension of our trade in earthenware with the continent of Europe."

As it is always valuable to know what intelligent foreigners think of us and our manufactures, it may be well to close this chapter with a quotation from M. Kohl's recent work on England:—"If we compare the common

[Transferring the Print.]

earthenware of England with that of the French and Germans, or of any other nation, it appears not only excellent in quality, but also highly ornamented and unsurpassingly beautiful. The common French and German earthenware is comparatively ugly, coarse, and misshapen. On the other hand, English porcelain, as I have already remarked, particularly those articles in which elegance and beauty are the main points aimed at, are far behind those of the Continent. I believe there is something characteristic of the English in this. In articles of ordinary use, the English seem better than we to know how to combine excellence of quality with outward elegance and beauty; whereas in those articles in which grace and beauty alone are to be kept in view, the English are never equally successful." It is with the express view of elevating the taste of manufacturers in these and similar respects that "Schools of Design" are being established in the manufacturing districts.

CHAPTER VII.

ON THE STREET-GAS MANUFACTURE.

STREET GAS, according to familiar and every-day notions, is not exactly a 'chemical,' nor is it exactly a 'manufacture;' yet it would be difficult to find a train of operations more fitting to be included under chemical manufactures than this, and we will therefore devote a chapter to its consideration.

What Dr. Arnott says of the water-pipes of London, ramifying through every street, and lane, and alley, and distributing their valuable contents to the dwellings of its inhabitants, we may to a certain extent say of the pipes through which our supply of gas is obtained. "The supply and distribution of water in a large city, since the steam-engine was added to the apparatus, approaches closely to the perfection of Nature's own work in the circulation of blood through the animal body. From a general reservoir a few main pipes issue to the chief divisions of the town; these send suitable branches to every street, and the branches again divide for the lanes and alleys; while at last into every house a small leaden conduit rises, and, if required, carries its precious freight into every apartment, where it yields it to the turning of a cock." The analogy is true so far as regards the emanation from a centre, the branching out of minor pipes from those of larger diameter, the lateral small pipes leading into the houses, and the concealment of the whole assemblage beneath the pavement and roadway; but the subsequent movement from the branches back again to the centre, though observable in the flow of water through drains into the rivers and seas, the evaporation from thence, and the feeding anew the springs from which the supply was originally obtained, is not so observable in the gas circulation.

Be the analogy what it may, however, no thinking person can fail to be struck with the admirable means whereby our cities and towns are now lighted. So far back as the year 1823, when gas companies were comparatively in their infancy, a Committee of the House of Commons spoke highly of the system of lighting streets by gas, as a measure of street police; and there can be no question that the doers of evil, who "love darkness rather than light," infest the streets of London not only relatively, but positively less now than before the introduction of gas, although the inhabitants have increased three or four hundred thousand in number. The beauty and convenience of the light afforded by gas in streets, shops, and buildings, are appreciated by all; but the protection which it gives, though not so fully understood, is not less worthy of notice.

It will be convenient at once to enumerate, before describing the arrangements of gas-works, the successive steps or stages in the process. 1st. The carburetted hydrogen, which constitutes the gas for illumination, is one of the ingredients in common coal, and is separated from it by distilling the coal in highly heated vessels secluded from the access of the air. 2d. The substance left behind in the heated vessels or retorts, after the volatile portions have separated from it, forms the fuel known as coke, which is either sold to other parties, or is used with or without admixture with coals to heat the retorts. 3rd. The volatilised ingredients are so far from being pure carburetted hydrogen, that they comprise tar, ammonia, sulphuretted hydrogen, and other substances, all of which must be removed before the light-producing ingredient will be in its proper degree of purity; and the first part of this purification is effected by a piece of apparatus called a hydraulic main, in which the coarser impurities are deposited. 4th. The gaseous product passes through pipes, which are either immersed in cold water, or are sprinkled by a jet of cold water externally; whereby all the impurities which are in the gaseous form only at high temperatures are condensed, and fall into a vessel beneath; hence this process is called condensing. 5th. The remaining gas contains sulphuretted hydrogen, as well as carburetted hydrogen; and in order to remove the former, the whole is agitated in a vessel containing either lime or lime-water, which combines with the deleterious ingredient, and leaves the carburetted hydrogen tolerably pure. 6th. The gas thus made is conveyed through pipes to immense store-vessels called gasometers or gas-holders, where it is kept out of contact with the atmosphere by inverting the vessel in a tank of water. 7th. The gas passes through a meter or measurer, whereby the whole quantity made throughout a given period, and the rapidity of formation at any particular point of time, are determined. 8th and lastly. The gas is conveyed from the meter to the various streets and buildings by pipes laid underground, the supply being regulated to the demand by gauges and valves placed near the meter.

The establishment of the large gas-works of London was an enterprise beset with numerous difficulties. Mr. Winsor, after lecturing on the subject at the beginning of the present century, formed a "National Light and Heat Company," which, though built upon rather fanciful grounds by the projector, became the parent of all the gas companies, and has ever since taken the lead among them. The works were established at Westminster, forming a portion of the present large station there. Mr. Matthews, who wrote a History of Gas-lighting about fifteen years ago, takes the following view of the establishment of Mr. Winsor's company, which had become a chartered body:—"Various and plausible as were the objections urged against it at the time, experience has proved that the property of an individual was neither adequate to the magnitude, nor likely to be risked in such large and expensive undertakings; and this was shown by some facts adduced in the evidence to support the bill. By calculations that were made from actual surveys, it appeared that the expense of laying down pipes for the city of Westminster alone would be one hundred and fifty thousand pounds, without including anything else. There were also other circumstances that entitle this company to particular attention; for, previous to this period, their experiments for making, purifying, and applying the use of coal-gas to the purposes of lighting, had been made on a large and expensive scale. And although the public had been partially benefited from the knowledge obtained by their means, hitherto no pecuniary advantage had resulted to themselves, notwithstanding their zealous exertions to improve and introduce the art of gas-lighting. However, the hope of future benefits animated them in their further efforts to attain their object. Perseverance enabled them to overcome the great difficulties which attended their pursuits; the success of their endeavours has excited and encouraged others to engage in the same course, and imitate their example; and how many similar companies may trace their origin to the stimulus produced by the successful establishment of this!" The buildings which had been erected at the Westminster station before Mr. Matthews wrote, together with those which have been subsequently added, have cost no less a sum than three hundred and fifty thousand pounds.

The following description of one of the great London gas-works will convey a general idea of all. On passing through the entrance-gates, we see on the right hand a range of offices and counting-houses called collectively the 'Coke-Office,' while another range on the left hand is occupied as the 'Light-Office.' In these ranges of buildings are the offices for the Committee of Management, the superintendent, the clerks, and others engaged in counting-house duties. The terms 'coke-office' and 'light-office' relate to the two great departments into which the operations of most or all gas companies are separated; for the sale of the coke produced in the manufacture of gas, though certainly subordinate to that of the gas itself, is an item of great importance, and receives a proportionate share of attention. If coals could be brought to the London market at a price somewhat proportionate to that demanded at the pit's mouth, the sale of coke would not be looked to as a matter of so much importance; but the enormously high price which London manufacturers of every kind, as well as private persons, have to pay for coals, renders it necessary for the gas manufacturer to attend to the production of coke, either for heating the retorts or for sale. The kind of coal employed is selected not with relation to the absolute quantity of gas which it will yield, but with reference to its yielding both good gas and good coke. In our common domestic fireplaces we know that one kind of coal will concrete into a mass by a sort of semi-fusion, forming cinder; while another sort will burn away to a white ash without producing cinder. Similar differences exist in the combustion of coal in retorts; and the gas manufacturer for the most part rejects that quality which will burn away to a white ash. One portion of the coke produced at the works is afterwards used in the ovens or furnaces to heat the retorts, and the remainder is sold to manufacturers, dealers, and private persons. The 'coke-office' is the place where all the arrangements connected with the sale of the coke are carried on; while the clerks in the 'light-office' similarly manage the dealings of the Company with the gas consumers.

The two offices just named lie at the southern end of a large quadrangle or court, and from them we proceed to the other buildings, turning to the right after passing the entrance-gates. At and adjacent to the south-east corner are four of those bulky vessels which form the most conspicuous objects in a gas factory. The term *gasometer* applied to these vessels is a very inappropriate one, inasmuch as it conveys an idea of measurement as connected with the purpose of the vessel; whereas the gasometer is in truth nothing more than a gas-holder, in which gas may be accumulated and stored. In the earlier history of the manufacture, however, the gas-holder was made to serve the purpose of a gas-measurer, by the addition of a scale of feet and inches, so that the depth of gas in the vessel, multiplied by its area, gave the cubic contents; and thus the term 'gasometer' became introduced. So far as regards the quality and efficacy of the gas, a gasometer might be dispensed with, the gas being conveyed at once from the purifiers to the mains and burners; but it would be impossible thus to regulate the supply to the varying demand. As a shopkeeper provides a store of goods more than sufficient for immediate demand, in order that he may be prepared for future fluctuations, so must the gas-works accumulate during the daytime a quantity of gas adequate to the enormous and sudden demand which occurs about dusk. From the first establishment of gas-works it was found necessary to provide this reserve store, but it was hoped that some means would be discovered of dispensing with the bulky gasometers. Such means have, however, not been found, and all the gas-works exhibit these capacious reservoirs. Persons to whom the arrangement of gas-apparatus is not familiar, are often surprised at the different appearance which a gasometer, as seen towering above the wall of a gas-factory, presents at different times. At one period a kind of scaffolding of light and elegant iron-work is seen, forming a triangular space, within which an enormous cylinder stands at a small height from the ground; at another time, perhaps, after an interval of a few hours, the cylinder will be seen to have ascended ten or twelve feet; and at a subsequent period to have ascended nearly to the top of the framework forty or fifty feet in height. These differences may be easily understood if it be borne in mind that a gasometer consists in reality of two vessels, one within another, the outer one being a tank open at the top and closed at the bottom, and the inner one being an inverted vessel open at bottom and closed at the top. The tank is filled to a certain height with water, into which the inverted vessel dips, so that the interior of the latter is cut off from communication with the external air by the interposition of the water. A pipe passes into the tank quite through the water, and terminates in the vacant space within the cylinder; and through this pipe the gas, when completely made and purified, is conducted. Now, as carburetted hydrogen (common gas) is not half so heavy, *i. e.* has not half the specific gravity of atmospheric air, a certain bulk of it collected in the cylinder gives an ascensive power to the latter, notwithstanding the ponderous character of the metal; and the cylinder rises higher as the quantity of the contained gas increases. Balance-weights are suspended outside the gasometer to counterbalance in a certain degree the weight of the iron cylinder; and these weights are so adjusted as to give to the gas a pressure or elastic force slightly greater than that of the atmosphere. The reason of a gasometer rising, then, when full, is that the iron gasometer with its included carburetted hydrogen is lighter than an equal bulk of atmospheric air.

The tank of a gasometer is made of cast-iron, while the gas-holder is formed of sheet-iron, the sheets being riveted at the edges, and a piece of string being inserted at every joint, to make it air-tight—a simple but valuable contrivance suggested a few years ago by a workman. In some cases a strip of tarred canvas is inserted at the joints, or else canvas coated with white lead.

The four gasometers described as occupying the south-east corner of the quadrangle have what is termed the telescope construction, in which there are two gas-holders, one within another, and both within the tank; the inner gas-holder is filled first, and then, by an ingenious contrivance, elevates the outer one as the gas continues to enter; the object being to gain a greater capacity without increasing the diameter of the vessels, since the increased height of the apparatus is not so costly as an increased ground area. The tanks of these gasometers are about forty feet in diameter and eighteen feet high; and the gas-holders when full reach to a height of nearly forty feet. About twenty years ago there were some strange misconceptions afloat respecting the danger to be apprehended from the explosion of gasometers; but in the Report of a Committee appointed by the House of Commons to investigate the matter, the following remark set the doubts at rest:—"As long as every part of this reservoir is kept in good repair and perfectly tight, the pipes leading into and out of it maintained in proper condition, and plenty of water supplied, so that the parts which should be under water shall never be left bare, it seems to your Committee scarcely possible that any explosion should take place." The experience of subsequent years has shown that the gasometers are perfectly safe, and they are now made of much larger dimensions than any known at that time. The average capacity of the four alluded to above is about forty-five thousand cubic feet each. Some of the gas-works have gasometers very much larger than these.

Between or adjacent to the gasometers are cisterns whose use curiously illustrates the branches of commerce which arise out of the gas manufacture. We have slightly noticed the separation of a liquid containing the alkali ammonia from the other products of the combustion of coal. This ammoniacal liquor was at first a trouble and a burden to gas manufacturers; but after a time a market was found for it, and it is now regularly purchased by the proprietors of chemical works, as a source whence ammonia, or some of its compounds, may be obtained. The tar, which is another product of the combustion of coal in retorts, and of which more than a hundredweight is produced from a chaldron of coals, is separated from the gas by the same process, and in the same vessels as the ammoniacal liquor, and is in fact mixed with it; but as the tar has greater specific gravity than the ammoniacal liquor, it gradually assumes the lowest place in the vessel, and is then easily separated. Different plans have been adopted at different establishments in appropriating the tar thus produced; some sell it at once, as fast as it is produced; some consume a portion of it as fuel in the retort-house; while others, by a process of distillation, separate it into a volatile oil or naphtha, a fixed oil, and a solid residue nearly resembling common pitch.

Northward of the gasometers and the tar and ammonia vessels is a roofed building called the 'condensing or purifying house,' filled with a complicated series of vessels, employed, first, in condensing all those impurities which are capable of condensation, and, secondly, in purifying or separating the gas from a portion of sulphuretted hydrogen which is always produced with it, and which, besides interfering with the brilliancy of the light, would produce a most disagreeable and unwholesome odour. Condensers of a great variety of forms have been used at different times and in different establishments; but those at the works under consideration consist of a pipe with a number of ascending and descending bends in it, and short pipes at the lower end to allow the tar and ammonia to flow out. A constant stream of cold water is flowing down the outside of each pipe, by which the gas, as it passes through, is cooled, and the condensible impurities separated from it. From the condenser the gas passes to the purifiers, of which there are three complete sets in the purifying-house, each set consisting either of three or four large cast-iron vessels. Without going into minute details, we may just state that the three or four purifiers forming one set are placed side by side, but at different elevations; that each vessel is supplied with lime-water, which is kept constantly stirred by a revolving apparatus within; that the gas passes successively through all the vessels, parting as it goes with its sulphuretted hydrogen, which combines with the lime-water. The lime-water is changed frequently when it becomes too much sulphuretted, and matters are so arranged that one bushel of lime will purify twenty thousand cubic feet of gas. The rotating machinery in the purifying vessels, the working of the pump in the well, and the removal of the tar and ammoniacal liquor from one vessel to another, are effected by steam-power.

The next building to the purifying-house is one in which the sulphuretted lime undergoes certain processes, after being removed from the purifiers. Some of the most important improvements in the gas manufacture relate to this part of the proceedings. The lime-water is conveyed from the purifiers to a large underground cistern, and from thence to a range of cast-iron vessels, in what is termed the 'pug-mill room,' where it is allowed to settle, by which the principal part of the lime subsides and separates from the sulphuretted liquor. The lime is then taken to a 'pug-mill,' a sort of a churn, and there mixed up with clay, to form a cement or 'lute' for securing the covers of the retorts. The liquor is wholly evaporated, or driven off in the form of steam, by pouring it into shallow pans occupying the floor of the furnaces or ovens in which the retorts are heated. This mode, so far from being inconvenient, is productive of benefit in another way; for the steam arising from the liquor tends to cool the bars of the furnace, and thus to preserve them.

Next to this building is a carpenter's shop, in which wood-work for various purposes connected with the factory is made and adjusted. Adjoining this is a store-room for fire-bricks (used in the retort furnaces) and some other articles; and in the open area in front are two large vessels, called saturators, through which the whole of the gas passes after leaving the purifiers and before being conducted to the gasometers. The gas is, by a peculiar arrangement, subjected to a chemical process which gives it a very high degree of purity, by abstracting all the ammonia.

We have now passed along the eastern side of the large quadrangle, the open area of which exhibits much bustle and activity. Here waggons laden with coals and passing to the coal-stores; there waggons and carts belonging to dealers in coke, who have come to purchase; in one place heaps of iron pipes; in another, of retorts, about to be put in the place of old ones; while men are bustling about in all directions. In crossing over to the western side, past the end of the central building, we catch an end glimpse of two of the retort-houses: through a dark arch the eye can just discern the movements of men passing to and fro in front of the retorts, while an occasional gleam from the retorts themselves suddenly lights up the spot.

The western side of this quadrangle is occupied almost entirely by gasometers, enclosed in brick buildings without roofs. A portion of the space is, however, occupied as a coal-store, one of the many receptacles for the vast quantity of coals consumed here. A contemplation of such immense supplies of fuel, and of the invaluable services derived therefrom, brings to mind the remark of an elegant writer, that the coal-mines of Britain " are, in effect, mines of labour or power, vastly more precious than the gold and silver mines of Peru, for they may be said to produce abundantly everything which labour and ingenuity can produce, and they have essentially contributed to make her mistress of the industry and commerce of the earth. Britain has become to the civilised world around nearly what an ordinary town is to the rural district in which it stands, and of this vast and glorious city the mines in question are the coal-cellars." Fears have been entertained by some that the time must be looked forward to when this precious supply will fail—when the mines, worked at their present enormous rate, will no longer yield their wonted product. But the more investigations are made, the more remote seems to be the time when such a misfortune will befall us; and we may safely leave to future ages the adoption of a remedy, if not a prevention.

There is an inner quadrangle, containing another series of condensing and purifying apparatus, comprising vessels similar to those before described, as well as an ammonia tank, pumps, &c. Beyond these, on the right, is a large smiths'-shop, where men are busily engaged in the repair and adjustment of various articles used in different parts of the works. The gasometers, condensers, purifiers, tanks, retorts, mains, pipes, and other iron-work of magnitude, are of course made at the large foundries, but there are abundant demands for smiths'-work on a smaller scale at such an establishment as this. The northern end of this smaller court is occupied principally by one gasometer, the largest in the establishment, having a capacity of eighty thousand cubic feet: it is well placed, and has an imposing appearance, especially when raised to a height of fifty or sixty feet. On the left or west side of the court are two of the four retort-houses—iron-roofed buildings, in which the gas is made. The arrangement of these houses we shall speak of presently, and need only say here that these two present the same striking and remarkable features which characterise the other two. In the open court of the quadrangle are indications of the same traffic and bustle which the other presents: the arrival and unloading of cargoes of coal, the heaping and sprinkling of the heated coke just brought smoking and steaming from the retort-house, &c. At various convenient places in this, as in the other quadrangle, are store-houses for coal, from whence the retorts are supplied; and in addition, wherever room could be found for them, gasometers are placed.

We have now noticed the principal buildings, apparatus, and general arrangements round both quadrangles of the establishment, and will next return to the one first described, and take a hasty glance at the building in its centre. This building is divided into various departments, such as a deputy superintendent's office, an inspector's office, a meter-room, a valve-room, two retort-houses, a coal-store, a coke-store, an engine-room, &c. The four first-mentioned rooms form a kind of additional building attached to the southern end of the remainder, and, with its motto "STET CAPITOLIUM FULGENS," is the first object which meets the eye from the entrance. The retort-houses are built at a few feet distance from the ground, leaving space beneath for the coal and coke stores.

Whoever enters for the first time into a retort-house cannot fail to be struck with its appearance, so different from that of most other factories. The iron roof, the iron floor, the absence of windows, the absence of machinery and work-benches, the strange appearance of the walls speckled over with complicated iron-work (whose purpose is not clearly discernible), the darkness of the place, the appearance of the men—all have an aspect of strangeness. But at intervals of every hour or two, and especially at night, the visitor's attention is suddenly awakened to a startling scene going on within the building. He sees a party of men advance to one part of the side apparatus; he sees them turn the handles of what appear to be screws; he hears several explosive reports, followed by the removal of circular iron doors or covers about a foot in diameter; he sees a burst of flame from each hole whence a cover has been removed; and on going in front of one of these openings (if he have courage enough) he will perceive a mass of intensely burning coal, or rather coke, extending back to the depth of six or seven feet. Then will follow the removal, by means of rakes, of all the burning materials from each opening; then the hissing and steaming consequent on the wetting of the coke by buckets of water; and then the re-charging of the heated cavity with fresh coals. It is not until after noticing this succession of operations that a stranger can rightly understand the arrangements of such a place.

They are—with slight exceptions, which we need not heed here—as follows: Each side of the retort-house has a succession of arched recesses, each eight or ten feet high, six or seven wide, and about as many in depth. These recesses, when bricked or otherwise closed in front, form ovens or furnaces, in which fuel is burnt on a grate at the lower part. Five, six, eight, or more oblong iron vessels, each holding from two to three bushels of coals, are ranged horizontally in this oven, from front to back, so that the heat, flame, and smoke from the furnace may play around them, and make them red-hot. The outer end of these vessels, which are the *retorts* (a name for which we have never heard a good reason assigned), are left open or closed as occasion may require; an iron door, connected with a screw, being accurately fitted to each retort. The retorts are semi-cylindrical in shape, with the flat side placed lowermost. The average height of the retorts is perhaps about five feet from the ground; under them is a fireplace, through which the fuel is introduced by which they are heated; and under this again is a kind of ash-pit or shallow vessel into which the lime-water is poured for the purpose of evaporation. The operation then consists in this:—The empty retorts are first brought to a red heat; then a 'charge' of coals is introduced; then the cover is screwed on the end, and made air-tight by a cement of clay and lime. Thus the retorts remain for about five hours, during which the fireplace is opened every hour for the renewal of the fuel with which the retorts are heated; and at the end of this time all the gaseous and vaporisable matters having left the coal, and passed up from each retort by a pipe into the 'hydraulic main,' the 'drawing of the retorts' commences. The retort-cover is loosened by turning a screw; a slight explosion takes place when communication with the atmosphere is opened; the cover is removed by the sooty and almost fire-proof hands of the men, and the coke is drawn out by means of rakes eight or ten feet long. A kind of box, made entirely of iron, and placed upon wheels, is wheeled beneath the front of the retorts, and into it a portion of the fiery contents of each retort is drawn. The box is wheeled away, and in a few minutes volumes of steam are ascending profusely from it, the result of a plentiful supply of water, which is thrown on it for the sake of speedy cooling. The remainder of the coke is then drawn out on the iron floor of the building, and, after being partially cooled by water, is removed out into the open air.

In the upper part of every retort is an opening from which ascends a vertical pipe three or four inches in diameter. The gas, as it is formed, having no other outlet, ascends this pipe, passes thence to another pipe placed horizontally, and then enters a descending pipe, which dips into a large main fourteen or fifteen inches in diameter. This main is placed horizontally along the whole length of the retort-house, and receives all the gas from the whole range of retorts on one side, there being two mains on opposite sides of each retort-house. In these mains commences that purification of the gas which is the object of four successive processes, carried on in four distinct kinds of apparatus, viz. the hydraulic mains, the condensers, the purifiers, and the saturators. As may be readily supposed, the transference of the various products—such as gas, tar, ammoniacal liquor, &c.—from

vessel to vessel, requires a large assemblage of pipes, some of which are carried underground, and others within view.

The retort-houses, such as we have just described, are four in number; two situated in the northern quadrangle, and the other two being placed parallel and contiguous in the central building of the southern quadrangle. From these we pass to a series of smaller rooms attached to the southern end of the retort-houses, and within view from the entrance-gates. One of these is the office of the deputy-superintendent of the works, and the other two contain very ingenious specimens of apparatus whereby he can regulate the supply of gas at all hours of the day, calculate how much gas has been made within a certain period, ascertain the rate at which it is being manufactured at any particular time, and keep a check over the labours of the men. One of these rooms is called the 'valve-room,' and contains the apparatus for regulating the pressure and supply of the gas. To understand the use of such apparatus, it is necessary to recal to mind the striking change which occurs throughout London as evening is drawing on. The lamplighter is seen busily hastening from lamp to lamp, placing his slight ladder against the street lamp-irons, and kindling the flames which give to our streets no small share of their evening attractions; the shopkeeper begins to illuminate his wares, with one blaze if he be an humble dealer, with a dozen if his house be a 'gin-palace,' with a score or two if he sells 'unparalleled bargains' in linen drapery; the theatres, the club-houses, the evening exhibition-rooms —all begin to display a blaze of light near about one time. Now it must be obvious that the sudden demand thus created is enormous, and it may easily be conceived that great judgment is required in adjusting the supply. In order that the gas may be propelled through the main-pipes from the factory to the remotest point supplied from the works, it is necessary to give the gas a pressure or elastic force greater than that of the atmosphere. If this pressure be too small, the lights at remote places would burn much too faintly; if too large, the flames would become so strong as to consume an inordinate quantity of gas; if the gas flowed from the gasometers at an hour before dusk at the same rate as at an hour after dusk, the utmost confusion and irregularity would occur. To obviate these evils is the object of the pressure apparatus. Around the valve-room are placed valves connected with each great main. There are six mains branching out from the factory in as many different directions, for the supply of different parts of the town; and as each main requires a supply of gas proportionate to the nature and extent of the district through which it passes, a pressure-apparatus is attached to it distinct from the others. Directing our attention to one main only, we may state that after the gas leaves the gasometers and enters the main, it is placed in communication with a small tube leading to a 'pressure-indicator,' by which the exact pressure at any time of the day or night is determined. So long as the pressure is such as is required, no changes are made; but when it is either too great or too small, recourse is had to a valve, whose interior apparatus is in connection with the main. If the pressure is too great, the valve is drawn partly across the main, by which the supply of gas is slackened: if too small, the valve is opened more than before, to admit a greater volume of gas. These adjustments are, as was before observed, made in the 'valve-room,' every main having its own 'pressure-indicator' and its own 'valve.'

A room adjacent to the one just mentioned, and called the 'meter-room,' exhibits to view a cast-iron case of a very tasteful kind. This case is probably about ten feet square, and seven or eight feet high, and occupies the centre of the room. On the front are six or eight small dials, like clock-faces, and at the back are two pipes ascending through the floor, and entering the case. The case is decorated with much elegance, and the motto, "EX FUMO DARE LUCEM," expresses, not inappropriately, the light-giving object of the whole establishment. All the gas made at the works passes into this case or 'meter' by one of the pipes just spoken of, and leaves it by the other. The meter will contain a certain known quantity of gas; and while this quantity is passing through the machine, an index hand is caused, by mechanism within the case, to revolve once round a dial-plate. Every ten revolutions of this hand causes another index to revolve once round another dial-plate; ten of these latter revolutions cause one revolution of a third index; and so on through six successive stages, the last index revolving only once while a million cubic feet of gas are passing through the meter. The superintendent, by looking at the indications in these six dial-faces, is thus able to tell, even to a single foot, how much gas has passed through the meter to the main pipes. There are two other dials on the front of the meter, one of which is a regular clock, and the other an ingenious arrangement for showing the rate at which the gas is passing through the meter at any particular time.

The operations of a gas factory are interminable from the beginning to the end of the year. No cessation, even for a moment, occurs in the labours. One party of men are engaged at night; another party relieve them after an interval of twelve hours, and are employed by day; but the furnaces are always heated, the retorts always supplied with their fiercely burning contents, the gas always undergoing the purifying processes previous to its passage into the gasometers. The number of retorts worked varies at different seasons of the year, according to the length of time between sunset and sunrise; for the gas-manufacturer is regulated, more perhaps than most other manufacturers, by the movements of the sun. But whether the number actually worked at any one time be greater or smaller, the system pursued is nearly the same. At the works we have noticed, the retorts are so divided into groups that some of them shall be ready for 'drawing' every hour. If we suppose, for instance, that a charge of coals remains five hours in the retort, and that the retorts are divided into five parcels or sets, one set would be filled (say) at noon, another at one o'clock, and the rest at two, three, and four o'clock respectively. Then, by five o'clock the first set of retorts are ready to be drawn; at six o'clock the second set; and so on with the others. The precise arrangements we need not enter into, but it will suffice to say that exactly as the clock strikes each successive hour, the men loosen and remove the covers of the retorts, draw out a portion of the coke into large iron boxes, draw out the rest upon the iron floor of the retort-house, throw water on the coke preparatory to its removal from the retort-house, recharge the retorts with fresh coal, replenish the fires with a fresh supply of coke, and fit the covers—coated on their inner surface with a thick layer of lime and clay cement—firmly on the mouths of the retorts. In the intervals which elapse between the successive ‘drawings,’ the men are employed in pouring the lime-water into the troughs beneath the fireplaces, in placing new layers of cement on the retort-covers to be used after the next drawing, in carrying out the coke into the open air, and afterwards into the sheds or stores, in bringing coals from the coal-stores to the retort-houses, in removing the ashes which fall into the lime-water in the ash-pit, and in various other duties subsidiary to the manufacture of gas. The subsequent preparation, or rather perfecting of the gas, demands but a small amount of manual labour; it is in fact performed by the steam-engine, which pumps up the water from the well, transfers from vessel to vessel the tar and the ammoniacal liquor abstracted from the gas, and sets in rotation the arms or fans in the purifying vessels.

There is perhaps no part of the gas mechanism which requires better workmanship and more careful attention than the pipes which convey the invisible agent from the works to the places where it is consumed. However perfect may be the mode in which the gas is manufactured, however plentiful the supply, yet if the pipes are either too small or too large, if they are laid either too horizontal or too much inclined, if any of the innumerable joints are imperfectly fitted, the most serious inconvenience results. The mains vary from three inches to eighteen inches in diameter, independent of the small lateral pipes which proceed from the mains into the houses. The largest mains are placed nearest to the gas-works; the next in size are appropriated to the leading streets and thoroughfares; while the smaller are for the less important lanes and streets. Where the streets are wide, and the number of lights required large, it is usual to lay mains on both sides of the street; and the diameters of these mains are made to depend not only on the magnitude and importance of the street, but on its elevation, its distance from the works, and other circumstances. There is a circumstance attended to in laying down the mains which is perhaps not generally known. They are laid with a gradual inclination, amounting perhaps to an inch in ten or twelve yards, instead of being horizontal; and when this slope has continued for one or two hundred yards, the mains begin to ascend in a similar degree. The line of mains thus ascends and descends alternately throughout its whole length. The reason for this arrangement is, that a small deposition of fluid takes place in the mains; and this fluid, by flowing down the inclined pipes, accumulates at the lower points, where two descending lines meet: here a reservoir is formed, into which the liquid flows, and by the occasional use of a small pump from above the inconvenience is removed.

How few persons would guess the length of these underground arteries! How few would suppose that the mains proceeding from one of the metropolitan works alone, and ramifying through the streets at the west end of the town, would, if laid in a straight line, reach from London to Bristol; or, if combined with the 'service-pipes' which pass from the mains to the houses, extend from London to Exeter! Yet such is the case. Rapid as has been the erection of new houses, the extension of the gas-manufacture has proceeded with immeasurably greater rapidity. In the year 1814 there was only *one* gasometer at the Westminster station of the Chartered Company, then the only company in London, and this gasometer held only fourteen thousand cubic feet. By the year 1822, according to a Report on the various gas-works, presented by Sir William Congreve to the Secretary of State, the Westminster works had reached the following position:—"The whole number of retorts which were fixed was 300; the greatest number working at any time 221; the least number 87. Fifteen gasometers, varying in dimensions, the contents computed at 20,626 cubic feet each, amounting to 309,385 cubic feet altogether, but never quite filled. The extent of mains belonging to this station is about 57 miles; the produce of gas, from 10,000 to 11,000 cubic feet from a chaldron of coals. The weekly consumption of coals is reckoned at forty-two bushels for each retort, amounting to about 602 chaldrons; and taking the average number of retorts worked at this station at 153, would give an annual consumption of coals of upwards of 9282 chaldrons, producing 111,384,000 cubic feet of gas. The average number of lights during the year 1822 was 10,660 private, 2248 street lamps, and 3894 theatre amps." In the interval which has elapsed since this eport was made, great extension has taken place in all he operations of the gas-manufacture, both in the number of works, and in the quantity of gas made at each.

Whether or not we accept the motto used by Mr. Matthews in his work on Gas Lighting,—

> "This is an art which doth excel nature,"

here is abundant room for admiration and congratulation in the history and application of this light-giving agent; and the following statement, from the 'Penny Cyclopædia,' shows how extensively the advantages are now appreciated:—"Every large town in Great Britain has long had gas; the smaller towns have followed, and there is now scarcely a place in the kingdom without it. The continental nations have slowly followed our example; Paris for some years, and more recently the towns of Lyon, Marseille, Bordeaux, Nantes, Caen, Boulogne, Amiens, and several others, have adopted it. It is in use in many parts of Germany and Belgium, and St. Petersburg has a small establishment which is rapidly increasing under the superintendence of a gentleman from one of the London works. The larger towns in the United States also burn gas; and even in the remote colony of New South Wales, the town of Sydney has introduced this valuable invention, which we have no doubt will be found there, as it has been in London, as useful in preventing nocturnal outrage as an army of watchmen."

THE END.

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